PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 6

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August, 1916

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(INSTITUTED 1852)

VOL. XLII—No. 6

AUGUST, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1916

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American Society of Civil Engineers

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TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Nelson P. Lewis, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

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The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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Vol. XLII. AUGUST, 1916. No. 6.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

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MINUTES OF MEETINGS

OF THE SOCIETY

May 17th, 1916.—The meeting was called to order at 8.30 P. M.; Vice-President Alfred Craven in the chair; Assistant Secretary T. J. McMinn, acting as Secretary; and present, also, 113 members and 19 guests.

The Assistant Secretary announced the death, on May 16th, 1916, of Elmer Lawrence Corthell, President of the Society. Dr. Corthell was elected a Member, September 2d, 1874, served as Vice-President in 1889, 1893, and 1894, and was elected President, January 19th, 1916.

The following telegram was read:

"Washington Branch sends deep regrets on death of President Corthell. His valuable works and writings are full of instruction to

the Profession, and his broad and honorable services will remain an inspiration to younger engineers for all time.

"ARTHUR P. DAVIS,
"*President,* Washington Branch."

The following motion, offered by A. C. Humphreys, M. Am. Soc. C. E., was unanimously adopted:

"As a mark of profound respect and in recognition of the great loss which this Society, the Engineering Profession, and the Country has sustained in the death of our President, Elmer L. Corthell, it is moved that, without transacting any business, we do now adjourn to a date to be set by the officers."

Adjourned.

May 24th, 1916.—The meeting was called to order at 8.30 P. M.; W. A. Cattell, M. Am. Soc. C. E., in the chair; Assistant Secretary T. J. McMinn, acting as Secretary; and present, also, 143 members and 18 guests.

H. de B. Parsons, M. Am. Soc. C. E., addressed the meeting on the subject "Engineering Fallacies", illustrating his remarks with lantern slides.

The Assistant Secretary read the following letter:

MAY 2ND, 1916.

"AMERICAN SOCIETY OF CIVIL ENGINEERS,
"MR. CHARLES WARREN HUNT, *Secretary,*
"220 West 57th Street,
"New York City.

"DEAR SIR:

"The National Guard of New York have inaugurated a campaign to obtain 3 000 recruits during the month of May, and as the Commanding Officer of the only organization of engineer troops in the State, I ask the co-operation and assistance of the American Society of Civil Engineers towards increasing the number of technically qualified men in this command.

"The armory is at 168th Street and Ft. Washington Avenue, Manhattan, where information can be obtained on Monday, Thursday and Friday evenings.

"I would thank you if you would make suitable announcement of this at your next meeting and post same on your bulletin board.

"Very respectfully,
"E. W. VAN C. LUCAS,
"*Lt.-Col.,* Commanding Corps of Engineers, N. G. N. Y."

E. F. Robinson, Assoc. M. Am. Soc. C. E., addressed the meeting on the subject of recruiting engineers in the National Guard.

The Assistant Secretary announced the following deaths:

CLOUD CLIFFORD CONKLING, of Buffalo, N. Y., elected Member, January 4th, 1905; died May 8th, 1916.

Frederic Charles Kunz, of Philadelphia, Pa., elected Associate Member, February 6th, 1895; Member, December 7th, 1898; died May 3d, 1916.

Theodore Hall McKenzie, of Hartford, Conn., elected Member, September 7th, 1881; died May 3d, 1916.

Henry Rohwer, of St. Louis, Mo., elected Member, April 1st, 1903; died May 4th 1916.

Adjourned.

June 7th, 1916.—The meeting was called to order at 8.30 p. m.; T. Kennard Thomson, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 85 members and 16 guests.

The minutes of the meetings of April 19th and May 3d, 1916, were approved as printed in *Proceedings* for May, 1916.

A paper by Elliott J. Dent, M. Am. Soc. C. E., entitled "The Preservation of Sandy Beaches in the Vicinity of New York City," was presented by the Secretary, who also read communications on the subject from Messrs. L. M. Haupt, Charles H. Higgins, and Allen Hoar.

The paper was discussed by Messrs. John C. Trautwine, Jr., A. W. Buel, and F. W. Schwiers.

A paper by R. C. Carpenter, M. Am. Soc. C. E., entitled "The Properties of Balsa Wood (*Ochroma Lagopus*)," was presented by the author, who illustrated his remarks with lantern slides and exhibited specimens of balsa wood and articles manufactured from it.

The paper was discussed by Messrs. Leonard M. Cox, A. P. Lundin, and the author.

The Secretary announced the election of the following candidates on May 31st, 1916:

As Members

William Edwin Brown, Brooklyn, N. Y.
Aaron Moulton Burt, St. Paul, Minn.
Francis Fair Gillen, Washington, D. C.
William Ignatius Klein, Kansas City, Mo.
Harry Charles Lothholz, Chicago, Ill.
Robert Spink Reynolds, New Haven, Conn.
Lindley Marshall Rice, Seattle, Wash.
Walter Adam Shaw, Chicago, Ill.
Simon Weinberg Tarr, Duluth, Minn.

As Associate Members

Orsino Paul Allee, Kansas City, Mo.
Frank Joseph Blair, Jr., State College, Pa.
Arthur Frederick Blaser, Cleveland, Ohio

John Boldt, Cleveland, Ohio
Fred Melvin Brown, Bozeman, Mont.
Harris Daniel Buckwalter, Harrisburg, Pa.
William Victor Burnell, Houston, Tex.
Edward Sherman Chase, Albany, N. Y.
James Harlan Cissel, Ann Arbor, Mich.
Robert Allen Conard, Jacksonville, Fla.
Frederick William Cottrell, Delta, Utah
Harold Joseph Crookes, New York City
Frank Hill Davis, Tuscaloosa, Ala.
Wilbur Earle Ferguson, Hastings-on-Hudson, N. Y.
Alexander Sylvester Forster, Toledo, Ohio
Walter Linder Foster, Sandpoint, Idaho
Frederick Herston Frankland, Lake Charles, La.
Forrest Faye Frazier, Manhattan, Kans.
George Hagbart Guerdrum, Christiania, Norway
Frank Demetrius Hayden, Seattle, Wash.
Robert William Heerlein, Pittsburgh, Pa.
Frederick Charles Hingsburg, New Orleans, La.
Charles Anthony Hochenedel, Fremont, Ohio
James Humphry, Jr., Springfield, Mass.
Harry Griffith Hunter, Kansas City, Mo.
George Augustus Jessop, York, Pa.
Zed Wilber Kent, Canton, Ohio
Mark Champion Krause, Williamsport, Pa.
Herbert Lawrence Luther, Leavenworth, Kans.
Henry Manley, Jr., Elmhurst, N. Y.
Roy Everett Miller, Seattle, Wash.
William Franklin Miller, Philadelphia, Pa.
Charles Elias Mollard, Chicago, Ill.
Robert Henry Moth, Cambridge, Ohio
Robert Rudolph Panzer, Cincinnati, Ohio
Louis Ray Parmelee, Helena, Ark.
Harold Frank Parsons, Huntington, N. Y.
Wallace Emery Parsons, Portland, Me.
Archibald Frederick Partridge, Mildura, Victoria, Australia
Laurence Patterson, Yonkers, N. Y.
Arthur Leonard Pauls, Boise, Idaho
Hector Somerville Philips, Toronto, Ont., Canada
Astley Bloxam Purton, Salt Lake City, Utah
Harrison George Roby, Alpena, Mich.
Charles Freeman Rohde, Brooklyn, N. Y.
Wilkie Claiborne Rohr, Charlotte, N. C.
Herbert Milton Rouse, Calexico, Cal.

Leopold Maurice Sandstein, New York City
Arthur Charles Sandstrom, Redwood City, Cal.
Roy Hopkins Shoemaker, Manila, Philippine Islands
Schuyler Morton Smith, St. Louis, Mo.
Arthur Emerson Sortore, Pittsburgh, Pa.
Burr Manlow Stark, Montclair, N. J.
William Stuart Tait, Lemont, Ill.
Samuel Locke Thomsen, Toledo, Ohio
John Edward Stirling Thorpe, Whitney, N. C.
Starr Truscott, Cristobal, Canal Zone, Panama
Warren William Upson, Hartford, Conn.
Andrew Vogel, Boston, Mass.
Frank Alanson Walton, Lansing, Mich.
Ernest Judson Waugh, Benton, Cal.
Max Wertheimer, Cleveland, Ohio
Walter Austin Wheeler, Kansas City, Mo.
Frank Wallace Whitlow, Milwaukee, Wis.
Albert Louis Wilcox, San Francisco, Cal.

As Associate

Elmer Earl Moots, Tucson, Ariz.

As Juniors

Ray William Berdeau, Paraiso, Canal Zone, Panama
Jay Cassius Canney, Seattle, Wash.
William Edward Fitzgerald, New Brunswick, N. J.
Frederick Henry Gross, White Plains, N. Y.
Dahyabhai Balabhai Kora, Gondal, India
Louis J. Larson, Champaign, Ill.
Raymond Matthew, State College, N. Mex.
Henry Conrad Neff, Adams, Mass.
John Robert O'Donnell, Brooklyn, N. Y.
William Sing-Chong Pung, Cushing, Okla.
Isadore Mendelsohn Sommer, San Francisco, Cal.
Frank James Soutar, Sioux City, Iowa
William Edward Stanley, West Lafayette, Ind.
Isaac Yost Stauffer, Batavia, Java
Clement F. Waite, Underwood, Wash.
Louis Shemald Youngling, New York City

The Secretary announced the transfer of the following candidates on May 31st, 1916:

From Associate Member to Member

Philip Lee Bush, San Francisco, Cal.
Clyde Greyson Conley, Mt. Vernon, Ohio

DONALD DERICKSON, New Orleans, La.
THEODORE GREEN, Buffalo, N. Y.
WALTER GLADDEN HUNTER, Stockton, Cal.
HENRY BURGER SAUERMAN, Chicago, Ill.

FROM JUNIOR TO ASSOCIATE MEMBER

THOMAS ABBOTT BALDWIN, Memphis, Tenn.
CLARENCE MYERS BATES, San Francisco, Cal.
WALLACE LAIRD CADWALLADER, New York City
WILLIAM GREENFIELD CORLETT, Oakland, Cal.
ORVILLE LAMONT ELTINGE, Kansas City, Mo.
LLOYD HARRISON FAIDLEY, St. Louis, Mo.
RUSSELL PLATT HASTINGS, Whittier, Cal.
LEON COHEN HEILBRONNER, Utica, N. Y.
KIKUMATSU HIRAI, New York City
LEON DAVID HOWLAND, LaGrande, Ore.
IRVING VAN ARNAM HUIE, New York City
ALBERT CARL KAESTNER, New York City
HUGH AMBROSE KELLY, Jersey City, N. J.
LLOYD MCENTIRE, Trenton, N. J.
HAROLD EDMUND MILLER, Providence, R. I.
CHARLES SIESEL RINDSFOOS, New York City
BURKE BROCKWAY ROBERTS, Cleveland, Ohio
JOHN HENRY SPENGLER, Richmond, Va.
RALPH BENJAMIN WILEY, West Lafayette, Ind.

The Secretary announced the following deaths:

AMORY COFFIN, of Phœnixville, Pa., elected Member, March 3d, 1875; died June 5th, 1916.

DAVID WEST CUNNINGHAM, of Montrose, Cal., elected Member, May 7th, 1873; died May 10th, 1916.

HENRY FLOY, of New York City, elected Member, June 6th, 1911; died May 5th, 1916.

JAMES VINCENT ROCKWELL, of Pensacola, Fla., elected Junior, April 3d, 1900; Associate Member, February 4th, 1903; Member, November 5th, 1907; died May 24th, 1916.

CHARLES SOOYSMITH, of New York City, elected Member, May 5th, 1886; died June 1st, 1916.

JAMES JEROME HILL, of St. Paul, Minn., elected Fellow, January 10th, 1889; died May 29th, 1916.

Adjourned.

FORTY-EIGHTH ANNUAL CONVENTION, HELD IN PITTSBURGH, PA., JUNE 27th-30th, 1916

FIRST SESSION *

Tuesday, June 27th, 1916.—The meeting was called to order in the William Penn Hotel at 10 A. M.; George S. Davison, M. Am. Soc. C. E., Chairman of the Local Committee of Arrangements, presiding; Chas. Warren Hunt, Secretary; and present, also, about 350 members and guests.

Mr. Davison introduced the Hon. H. M. Irons and the Hon. John A. Brashear, who addressed the meeting and welcomed the members to the City of Pittsburgh. Samuel M. Gray, M. Am. Soc. C. E., and Clemens Herschel, President, Am. Soc. C. E., also addressed the meeting.

The President delivered the Annual Address.†

Adjourned.

SECOND SESSION—BUSINESS MEETING ‡

Tuesday, June 27th, 1916.—The meeting was called to order at 2 P. M.; President Clemens Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, about 100 members.

The Secretary presented a report on the suggestions of members as to the time and place for holding the Annual Convention of 1917.§

On motion, duly seconded, the matter of the selection of the time and place for holding the next Annual Convention was referred to the Board of Direction, with power.

The Secretary stated that the only report expected from any of the Special Committees was that from the Special Committee on Concrete and Reinforced Concrete, but that none had been received.

It was moved and seconded that the Special Committee on Concrete and Reinforced Concrete be discharged. After discussion it was moved in amendment that the matter be laid on the table. The amendment, being duly seconded, was carried.

The following resolution, offered by John A. Ockerson, Past-President, Am. Soc. C. E., was adopted unanimously:

"We greatly appreciate the cordial welcome extended to us by the City of Pittsburgh through its official representatives; and while the interval between our visits has been a long one, we have watched with interest and pride the rapid development of one of the great industrial centers of the world.

"We congratulate the city particularly on its galaxy of great captains of industry, who have contributed so much to the develop-

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* For the Report in full of this meeting, see page 418.

† See page 835 of Papers and Discussions.

‡ For the Report in full of the Business Meeting, see page 431.

§ See page 431.

ment and progress of our whole country, and we look for even greater achievements in the future.

"To the local members of our Society, and their associates, one and all, we extend our hearty thanks for the generous provisions made for our entertainment and instruction during the Forty-eighth Annual Convention.

"We trust that we may again have the privilege and pleasure of enjoying the hospitality of this progressive city."

The following resolution, offered by George F. Swain, Past-President, Am. Soc. C. E., on behalf of a Committee of the Board of Direction composed of Past-President Ockerson, Past-President McDonald, and himself, was adopted unanimously:

"*Whereas:* It has pleased the Almighty, in His Infinite Wisdom, to remove from the scene of his earthly labors, Elmer Lawrence Corthell, President of the American Society of Civil Engineers; be it

"*Resolved:* That the members of the Society, in Annual Convention assembled, express their grief at the loss of so distinguished an Engineer and so lovable a Man, and their admiration for his many noble qualities of heart and mind. They are thankful that he was granted a life so long, so fruitful for the Profession and for Mankind; with pride and pleasant memories they testify to his eminence as an engineer, his enthusiasm for the best interests of the Profession, his sterling character as a man, his unswerving loyalty as a friend. With saddened hearts they deplore his loss, and extend their deepest sympathy to the family so heavily bereaved. With trust and faith they resign themselves to the will of Him who doeth all things for the best.

"*Resolved:* That these resolutions be transmitted to his family, and that a copy thereof be spread upon the records of the Society."

William N. Brown, M. Am. Soc. C. E., called attention to the matter of Government competition in engineering along certain lines, thus depriving engineers of employment.

The Secretary stated that, in reference to at least one of the Government departments, the matter had been referred to the President of the Society, but that nothing definite had been established as yet.

No action was taken.

The Secretary reported the result of the ballots on the proposed movement of the Society Headquarters from 57th Street to 39th Street, New York City.*

The Secretary announced the election, by the Board of Direction on June 23d and 24th, 1916, of 10 Members, 29 Associate Members, and 13 Juniors, and the transfer of 9 Juniors to the grade of Associate Member, and 18 Associate Members to the grade of Member.†

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* See page 458.
† See page 411.

The Secretary read a letter from Preston S. Millar, Chairman of the Administrative Committee of the Illuminating Engineering Lecture Course, announcing a series of lectures on illuminating engineering to take place in Philadelphia, Pa., on September 21st to 28th, 1916.

The Secretary announced the following death:

CHARLES HOPKINS CARTLIDGE, of Chicago, Ill., elected Member, May 4th, 1904; died June 14th, 1916.

George S. Davison, M. Am. Soc. C. E., Chairman of the Local Committee of Arrangements, made some additional announcements relating to the excursions and entertainments.

On motion, duly seconded, the Board of Direction was requested to frame suitable resolutions of thanks for the courtesies tendered by the City of Pittsburgh and the local members of the Society.

Onward Bates, Past-President, Am. Soc. C. E., explained the status of the work connected with the proposed memorial to the late Alfred Noble, Past-President, Am. Soc. C. E.

Adjourned.

ELECTIONS AND TRANSFERS BY THE BOARD OF DIRECTION, JUNE 23d-24th, 1916

ELECTED AS MEMBERS

JAMES EDWARD CARROLL, St. Paul, Minn.
FRANCIS LEE CASTLEMAN, Pencoyd, Pa.
NATHAN RANDALL ELLIS, San Francisco, Cal.
EUGENE HAMILTON HEALD, Chicago, Ill.
ELMER KIRKPATRICK HILES, Pittsburgh, Pa.
EDWARD JOSEPH NOONAN, Chicago, Ill.
AUGUSTUS LYON PHILLIPS, Philadelphia, Pa.
WILLIAM HERBERT VANCE, Stamps, Ark.
THOMAS ROBERT JOHN WARD, Lahore, Punjab, India
VICTOR WINDETT, Chicago, Ill.

ELECTED AS ASSOCIATE MEMBERS

JOHN ROBERT BAYLIS, Jackson, Miss.
JOHN HENRY CHANDLER, Bartlesville, Okla.
LUTHER THOMAS FAWCETT, Youngstown, Ohio
STANLEY HOWARD FRAME, Calgary, Alberta, Canada
FRANK RAYMOND GOODMAN, Prescott, Ariz.
JOHN GUINOTTE, Seattle, Wash.
JAMES HENDRICKS HALLETT, Jacksonville, Fla.
CHARLES ARTHUR HASKINS, Lawrence, Kans.
FREEMAN REGINALD HEWETT, Ritzville, Wash.
CHARLES MILTON HIESIGER, New York City

Charles Kaapke Horton, Houston, Tex.
Murray Lee Hutton, Burlington, Iowa
Alberto Angel Ibarguen y Pi, Pinar del Rio, Cuba
José Maria Ibarra Cerezo, Caracas, Venezuela
Frederick Tyler Lawton, Brooklyn, N. Y.
Alonzo Church Lee, Florence, Ala.
John Kilby McGrath, Baltimore, Md.
Frederick Meister, Hoboken, N. J.
Benjamin Franklin Miller, Jr., Meadville, Pa.
Harold Brown Miller, Pittsburgh, Pa.
Carl Hilder Nordell, Milwaukee, Wis.
Clarence Willard Post, Albany, N. Y.
Carl Roy Rankin, Groveland, Cal.
Julius Jennis Sorenson, Cuyamel, Honduras
James Arthur Sourwine, San Bernardino, Cal.
Henry Daniels Stowe, Philadelphia, Pa.
Francisco Teixeira da Silva Telles, Santos, Brazil
John Jay Vandemoer, Loma, Colo.
Otto Wolpert, New York City

Elected as Juniors

Guy Atkinson, New York City
Roy Prentice Bishop, Brooklyn, Iowa
Arthur Gray Butler, Louisville, Ky.
Harry Foster Ferguson, Urbana, Ill.
John Lyle Greacen, Brooklyn, N. Y.
John Milton Heffelfinger, Jr., Columbus, Ohio
Paul Loveridge Heslop, Memphis, Tenn.
William Moragne Husson, Jacksonville, Fla.
Harry Edward Jones, Allentown, Pa.
Joseph Louis Loida, St. Louis, Mo.
Hendrix Gilbert Lytle, Louisville, Ky.
Allen Pierce Richmond, Central Aguirre, Porto Rico
Arthur Peter von Deesten, Brooklyn, N. Y.

Transferred from Associate Member to Member

Walter Henry Allen, Chicago, Ill.
Robert Edmund Andrews, Bay City, Mich.
George Safford Beal, Harrisburg, Pa.
James Wartelle Billingsley, New Orleans, La.
Paul Darwin Cook, Sioux City, Iowa
Harry James Cowie, Niagara Falls, N. Y.
Malcolm Elliott, Louisville, Ky.
Walter Lewis Fitzgerald, Philadelphia, Pa.
Daniel Wingerd Gross, Wilmington, N. C.

JOSEPH FREDERICK JACKSON, New Haven, Conn.
FRANK PERRY LARMON, Utica, N. Y.
STANLEY ALFRED MILLER, Paducah, Ky.
CYRUS EDWARD MINOR, Chicago, Ill.
JOHN LYNCH O'HEARN, Oklahoma City, Okla.
HORACE PATTON RAMEY, Chicago, Ill.
DANA WATKINS ROBBINS, Utica, N. Y.
NED HENSEL SAYFORD, Memphis, Tenn.
GEORGE AUSTIN SHERRON, Norwalk, Conn.

TRANSFERRED FROM JUNIOR TO ASSOCIATE MEMBER

JAMES BUCKLEY BLACK, St. Louis, Mo.
HOWARD FRANKLIN BRONSON, Harrisburg, Pa.
FRANK EARLE DODGE, Hudson, N. Y.
EDWARD MURRAY FROST, Worcester, Mass.
LAURANCE HASTINGS HART, Buffalo, N. Y.
SOLON HERZIG, New York City
ARTHUR ANTHONY McLAREN, Cedars, Que., Canada
HERBERT MALCOLM PIRNIE, Springfield, Mass.
GLENN BARTON WOODRUFF, South Bethlehem, Pa.

OF THE BOARD OF DIRECTION

(Abstract)

June 23d, 1916.—The Board met at 10 A. M., at the William Penn Hotel, Pittsburgh, Pa., at the time of the Annual Convention, as required by the Constitution; President Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Cooley, Crocker, Davies, Duryea, Endicott, Fuller, Haskell, Hawley, Jonah, Keefer, Khuen, McDonald, Marx, Montfort, Ockerson, Ricketts, Swain, and Tuttle.

The death of Elmer Lawrence Corthell, President, on May 16th, 1916, was reported, and it was recorded that Clemens Herschel, the senior Vice-President, became President to fill the unexpired term, and Director Richard Montfort, the senior Director, became Vice-President to fill the unexpired term of Mr. Herschel.

Isham Randolph, M. Am. Soc. C. E., was unanimously chosen a Director to fill the unexpired term of Richard Montfort.

*Resolutions for presentation to the Business Meeting of the Annual Convention, and to be engrossed and forwarded to Mrs. Corthell, were authorized.

The following resolution was adopted:

"*Resolved:* That it is the sense of this Board that any officer succeeding to the unexpired term of any office occupies the same position as if elected by the Society to that office."

Mr. Davies, Chairman of the Committee on Special Committees, presented the following Report, which was received and placed on file:

"Report of Committee on Special Committees

"NEW YORK, May 15th, 1916.

"BOARD OF DIRECTION,
"American Society of Civil Engineers,
"220 West 57th Street, City.

"DEAR SIRS: In a report of the undersigned, your Committee on Special Committees, dated March 13th, 1916, presented to the Board of Direction on April 18th, 1916, there was contained a recommendation, in relation to the Committee on A National Water Law, that this Committee should be re-organized.

"Discussion of this subject referred the question of further investigation back to this Committee, and we now beg to report that we have made further investigation as to the work of this Committee, and recommend as follows:

"We requested Professor F. H. Newell, Chairman of this Special Committee, to advise us whether he felt that any work of permanent advantage could be accomplished by his Special Committee on National Water Laws, and in reply thereto Professor Newell states that

* See page 445.

'in his opinion results of large and permanent value will flow from the work of this Special Committee and that it is highly desirable that it be continued with perhaps fewer members'. Professor Newell goes into considerable detail in respect to the advantages of the work of this Special Committee.

"In the meanwhile this Committee took the liberty of communicating with the American Bar Association, and requested the American Bar Association to advise whether they considered that the Special Committee of the American Society of Civil Engineers was likely to be able to accomplish results which we had been given to understand the American Bar Association had failed in attaining, in connection with the study of A National Water Law. The American Bar Association referred this matter to Mr. Rome G. Brown, of Minneapolis, from whom we have received a valuable and instructive communication, the substance of which is summed up in the following:

"'For this reason it would seem to me that the Special Committee of your Society on this subject should not be terminated, but that your Society should appreciate the situation and should make further efforts in this matter. It should, it seems to me, see to it that its Special Committee on this subject is composed of men who are active, interested and informed, and that such Committee should co-operate in the work in Washington in promotion of these remedial statutes.'

"'It would seem to me that your Society could do most effective work by retaining this Special Committee and arranging for a more active co-operation in the work that is already being done.'

"Mr. Brown has also referred us to another member of the American Bar Association, who has made a particular study of this work and can give us further information. We find, however, that this gentleman is in the far West and is not likely to return East for some little time; but, in our opinion, such additional information as we can obtain will only strengthen us in our recommendation, that the Special Committee of the Society on A National Water Law should immediately be re-organized; that the entire present Committee as now constituted should be retired and that a new Committee be appointed consisting of Prof. F. H. Newell, as Chairman, with Mr. W. C. Hoad and Mr. John H. Lewis, as the other members thereof.

"This personnel is in accordance with the request of Professor Newell. We then recommend that the Board should give the fullest support to Prof. Newell, with this reconstituted Committee, to give the Committee every opportunity to prove its value and usefulness.

"We further recommend that as we cannot find any value whatsoever to the Society by the co-operation of the Special Committee on Floods and Flood Prevention with the Special Committee on A National Water Law, that the Special Committee on Floods and Flood Prevention should be terminated, in accordance with the request at the last Annual Meeting by the Chairman, Col. Townsend, as we fail to find any benefit or advantage in the co-operation of these two committees, and Col. Townsend's Committee has already tendered its final report.

"We beg to submit this with the request that the Executive Committee of the Board should act on this in advance of the next regular meeting of the Board of Direction.

"Respectfully submitted,

"J. VIPOND DAVIES, *Chairman,*
"VIRGIL G. BOGUE,
"LINCOLN BUSH."

The following resolutions were adopted:

"Resolved: That the Special Committee on A National Water Law be re-organized to consist of F. H. Newell, Chairman, W. C. Hoad, and John H. Lewis."

"Resolved: That the life of the Special Committee on Floods and Flood Prevention be terminated in accordance with the request of that Committee made through its Chairman, Col. Townsend, to the Annual Meeting in January, 1916."

The Secretary reported that through Director J. V. Davies $2 500 had been received from the Bethlehem Steel Company to be applied to the work of the Special Committees on Stresses in Railroad Track, and on Steel Columns and Struts.

*The Secretary presented the Report of the Tellers on the Canvass of Ballots on Proposed Movement of Society Headquarters, dated June 15th, 1916.

Resolutions were adopted for the carrying out of the expressed will of the membership of the Society in this matter.†

The Secretary reported that Messrs. George F. Swain and Stacy B. Opdyke, Jr., had been appointed as representatives of this Society on a Joint Committee of the four National Engineering Societies to prepare a report upon the advisability of the adoption of the Metric System as the practical standard in Engineering.

The following resolution was adopted:

"Resolved: That it is the sense of this Board that the President is a member of all Committees of the Society except the Nominating Committee."

The Secretary was instructed to call the attention of all Special Committees to this action.

A final appropriation of $3 240 to pay this Society's share of the expense of the International Engineering Congress was made.‡

H. R. Safford, M. Am. Soc. C. E., was appointed to take the place of William McNab, M. Am. Soc. C. E., on the Joint Committee on Stresses in Railroad Track, Mr. McNab having resigned as a member of the Committee.

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* See page 458.

† See page 459.

‡ The original amount underwritten by this Society as its share of these expenses was $9 000; 86% of this, or $7 740, has been called for, and has been paid.

The Constitution of the District of Columbia Association of Members recently formed was approved.

The Constitution of the Illinois Association of Members recently form was approved.

The Constitution of the Utah Association of Members recently formed was approved.

Ballots for membership were canvassed, resulting in the election of 10 Members, 29 Associate Members, 13 Juniors, and the transfer of 9 Juniors to the grade of Associate Member.

Eighteen Associate Members were transferred to the grade of Member.

Applications were considered and other routine business transacted.

The resignations of 1 Associate Member and 2 Juniors were accepted.

Adjourned.

June 24th, 1916.—The Board reconvened at the William Penn Hotel, Pittsburgh, Pa.; President Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bonteeou, Bush, Cooley, Crocker, Davies, Duryea, Endicott, Fuller, Haskell, Hawley, Jonah, Keefer, Khuen, McDonald, Marx, Montfort, Ockerson, Swain, and Tuttle.

A Report from the Membership Committee was received and acted upon.

Applications were considered and other routine business transacted.

Adjourned.

FORTY-EIGHTH ANNUAL CONVENTION, HELD IN PITTSBURGH, PA., JUNE 27th-30th, 1916

FIRST SESSION

Tuesday, June 27th, 1916.—The first session of the Convention was opened in the Ball Room of the William Penn Hotel at 10 A. M.; George S. Davison, M. Am. Soc. C. E., Chairman of the Local Committee of Arrangements in the chair; Charles Warren Hunt, Secretary; and present, also, about 350 members and guests.

THE CHAIRMAN.—The Forty-eighth Annual Convention of the American Society of Civil Engineers will now come to order.

Members of the American Society of Civil Engineers: It is forty-one years since last you were here. Forty-one years is a short time as the world goes, but this particular space of time, when measured by the achievements of the scientist and the engineer, marks a distinctive age of the world.

Those of you who were present on the other occasion, journeyed hither in wooden railway coaches; to-day you traveled in an all-steel train, a very recent addition to life protective measures; then you rode from the railway station to your hotel behind a single or a pair of old dobbins, to-day in a gasoline car, an invention of but fifteen years ago; then you did not convene on the seventeenth floor of the hotel, the tallest building in this city at that time being but six stories high, and that wonderful development of the engineer, the steel skeleton skyscraper being fully ten years in the future; then the human voice could not carry through walls and illimitable space, Graham Bell not having at that time made his telephone practicable; then the voice could not be preserved and reproduced, Edison having not yet made the phonograph a reality; then the most approved method of illumination was the light from a gas flame, it being three years later that incandescent electric lighting became a fact; then the science of aeronautics was confined to "going up in a balloon", it requiring twenty years thereafter for an honored member of this Society, Octave Chanute, first to establish the possibility of automatic equilibrium for air ships, thus creating a new word in the English language, to wit: aviation; then the dirigible torpedo had not been invented, that almost human thing which, coupled with the recently perfected submersible boat, is now the terror of the seas.

What changes has this period wrought upon our Society? Speaking briefly, it has been a time of strenuous growth and continued prosperity for the American Society of Civil Engineers. Then it had a total membership of not more than 400, now there are in its various grades about 8 000. Then it occupied rented quarters on East 20th

Street, New York City, with assets of not more than $10 000. For nearly nineteen years it has occupied its own property on West 57th Street and is reputed to be worth about $550 000. It has just voted by an overwhelming majority to dispose of its home, and become a joint occupant with other great Technical Societies, of a building which shall be a National Engineers Headquarters.

It may be interesting information, that, of the membership in 1875, there are but forty-seven now living, and of these but nineteen attended the Seventh Annual Convention, which, by the way, was among the first to be held away from New York City. Your Local Committee of Arrangements sent special invitations to these nineteen survivors for this Convention. Some have answered in person. The others have sent their regrets. As an example to us younger members, of the loyalty we should ever show to our Society, it is fitting we should hear them.

The speaker then read letters from: W. H. Wiley, New York City; Theodore Cooper, New York City; C. S. Maurice, Athens, Pa.; Marshall Morris, Waukesha, Wis.; F. B. Howard, Grosse Ile, Mich.; William Rotch, Boston, Mass.; Franklin C. Prindle, Washington, D. C.; W. D. Pickett, Louisville, Ky.; Joseph P. Davis, Yonkers, N. Y.; J. W. Hill, Cincinnati, Ohio; Charles Macdonald, Trenton, N. J.; J. F. Flagg, Santa Barbara, Cal.; W. H. Burr, New York City; and Robert Fletcher, Hanover, N. H.

This city is proud of the fact that it has furnished four presidents to this great Society: William Milnor Roberts, Max Joseph Becker, William Powell Shinn, and William Metcalf.

Of the present large membership, of which I spoke to you a few moments ago, 2½%, or practically 200 members, are residents of this city. In order to assure you that the citizenry of Pittsburgh is pleased to have you with us, I shall ask Mr. H. M. Irons, of the Legal Department of the City of Pittsburgh, who is here representing his Honor, Mayor Joseph G. Armstrong, to address you.

HON. H. M. IRONS.—Mr. Chairman, Ladies and Gentlemen, and Members of the American Society of Civil Engineers; Mayor Armstrong requested me first to say that he regrets very much his inability to be here this morning, but he has delegated me to say a few words of welcome for him.

After meeting many of the members of this Society, and after looking over this magnificent audience of great and intelligent men who have made the world move and who have wrought wonderful changes in the past 41 years, I know and feel that what Mayor Armstrong has lost in not being here has been to my infinite gain.

After listening to the remarks of the last speaker wherein he told you that through the efforts of scienee and through the achievements of the civil engineer, most wonderful advancement has been

made, and, when he told you something of the energy and the growth of this wonderful age in which we live, I could not help but think that we might go a step further and say that, since the discovery of this country, since the mind of man was given scope and given a chance to expand, it has produced marvels and wonders in four generations that eclipse and surpass the achievements of more than forty centuries. In four generations, the scientists, the discoverers, the inventors, the engineers, the real kings of the useful, have overcome the procrastinating efforts of time, and have brought about in a large degree the realization of the dream of centuries.

And you, gentlemen, are gallant enough and great enough to know that back of your great accomplishments, that back of your marvelous achievements, that back of all the wonderful things that you have produced stands the sweetheart, the patient wife, and the faithful mother. Back of man's success there is this inspiring influence that buoys him up in the sea of troubles and that drives him on through dangers and difficulties straight to the shining goal.

You, gentlemen, recognize the helpful companionship of your wives, and you herald that recognition to the people of Pittsburgh by bringing your wives and your daughters with you. We are all familiar with that old story of woman's listening to the conversation of the serpent and tempting Adam, and how through his fall man was thereby expelled from the glory of his first estate, but the fact that Adam put the blame upon his wife proves him unworthy of her, and, whether this story be true or not, I do know that the man who possesses the love of a good woman has not lost paradise but carries paradise with him wherever he goes.

Now in the name of the people of Pittsburgh and of all her daughters and her sons, I welcome you with all the cordiality contained in that one word "welcome". It has been 41 years since this Society last visited Pittsburgh, and I feel that we can go back and take up the story of the fellow who had wandered far from home, far from his father's house, and when he realized what he had lost he lifted up his eyes and beheld in dreams the glories of his father's house. So we, like the good father of old, will on this occasion, through the high offices of the City of Pittsburgh and the hospitality of our people, kill for the strangers and visitors within our gates the fatted calf, we will throw upon your shoulders the robe of hospitality, and we will welcome you and make you feel as though you had returned in very truth to the father's house.

It gives me great pleasure to welcome you, gentlemen, because I believe that this is one of the greatest and most widely known societies of the United States of America; one of the most technical, one of the most advanced societies, a society that has worked out and produced much of our present-day civilization. I am informed that wherever

we may go, wherever tunnels are bored through the hills, wherever bridges span the chasm or cathedral spires part the clouds, wherever man is marching in the van of the world's progress and mighty structures are being built, you will find a member of the American Society of Civil Engineers; and I believe it can be truthfully said that the sun in traveling around the globe never sets upon the members of this Society.

You will find that our cultured city possesses all modern improvements. It is a grand old commonwealth, nestling peacefully among the hills of Western Pennsylvania—a sort of glowing ruby of the robe of civilization. Pittsburgh is not progressive to the extent that her people have cast aside humanity and have anointed themselves with hypocrisy. She possesses for the poet, the philosopher, and the student an inexpressible charm. The banners of four nations have waved over her battlements. The French and English contended for the supremacy of this country at old Fort Duquesne. Here conferences with the Indians were held, the termination of which raised the banner of Washington, which still proudly fondles our air.

You must spend some time in sight-seeing. You will be shown many historical places, where great achievements have been wrought, and when you leave us, you will realize that every foot of our city is holy ground. You must visit our libraries and technical institutes, which perpetuate the name of Mr. Carnegie; our wonderful steel works and foundries which proclaim Pittsburgh to be the workshop of the world. By all means take an excursion to our South Hills, and from them look down upon our city at night, with its countless myriads of gleaming lights—one would think that the angels had spilled a basket of stars. The past, with all its glorious achievements, lies spread out before us in epitome. We can proudly boast of our tireless energy and the genius that gilds our name with glory, but we should not forget that what we are is only a prophecy of what we will be in the future, and when you come among us again our dreams will have become realities, and you will behold a more glorious empire than Greece or Rome ever saw.

You will find Pittsburgh just like all ordinary cities. She is bounded on the north by great ambition, on the south by indomitable energy, on the west by magnificent achievements, and on the east by the star of hope.

In welcoming this Society we cannot bestow upon you more laurels than you have won. We cannot honor you as you have honored us with your presence. Your presence among us means more to us than it can ever mean to you. May this meeting for the exchange of sentiments, of thoughts, of methods, of ideas and ideals, prove not only beneficial to you, gentlemen, who take part in the deliberations, but may it redound to the glory of humanity. May your stay among

us be pleasant and profitable, and when you depart and each and all shall go their separate ways, may something gathered here become an evergreen in the wreath of memory.

Before we part I shall recite to you a little poem which is the product of a Pittsburgh mind. It tells something of the truth concerning Pittsburgh, what Pittsburgh has accomplished, what Pittsburgh stands for, and what Pittsburgh wishes to be. It is beautifully expressed as follows:

"I am monarch of all the forges,
I have solved the riddle of fire,
The amen of nature and the good of man
Cometh at my desire.
I search with the subtle soul of flame
The heart of the hidden earth,
And from under my hammers the prophecies of
The miracle years go forth.
I am swart with the soot of chimneys,
I drip with the sweat of toil,
I quell and quench the savage wastes,
And I charm the curse from the soil.
I fling the bridges across the gulfs
That separate us from the to be,
And I build the roads of the bannered hosts
Of crowned humanity."

The Chairman.—It has been suggested that the persons sitting in the rear of the hall may not be able to hear the speakers. If that be true, there are plenty of seats up in front.

It is just as unnecessary to introduce some speakers to their audience as it would be to present to each other two old friends; and, though there is a lack of necessity in this particular case, I take great pleasure in introducing to you the first citizen of the State of Pennsylvania, a man who is great in his own simplicity, and in the affection in which he is held by all those who have come under his wonderful influence. He proposes to speak on the relation between science and engineering; and I introduce him to you in the terms that he loves to hear—"Uncle John, here is a fresh batch of nieces and nephews, go to it."

Hon. John A. Brashear.—My dear friends—I do not like to say, "Mr. President, Ladies and Gentlemen," because that puts him out of the running, but he is one of the decentest fellows that we have in this town, and we all love him.

The last time I spoke to an audience here, there were about eight hundred gathered in this room, all hard-headed business men, calling themselves the Creditmen's Association. I had a pretty hard time to get out of the hall after I had concluded my address. One of them said, "Look here, my old friend, are you going out and not

shake hands with me?" I replied, "Not if you will shake hands with me." "I want to shake hands with you and tell you that was a dandy address you gave us; but, when I saw on the programme that the Honorable John A. Brashear was to speak, I turned to the gentleman on my left, and said to him, 'Who is this man?' He evidently was a Pittsburgher and knew you and replied, 'Well, he is a celebrated astronomer; one of our greatest men;' and when I looked up on the stage and saw an old white-headed fellow sitting there, do you know what I thought?"—you will excuse me, gentlemen, for giving it to you in his exact language—"I thought what the hell are they going to give us now?"

I suppose he thought I was going to give them a lot of dry old figures that he could not understand, and that nobody else could understand; but I didn't do anything of the kind, and I hope I am not going to perpetrate anything of that sort on you to-day. I am very glad to meet and welcome you all, as did our good, loyal friend the last speaker, to the City of Pittsburgh.

I did not know it, but I was glad to learn that we had a lawyer who had the love of mother and wife and sister down in his heart, and was not afraid to come before you—and there are probably some bachelors here—and speak it right out.

Here is my dear friend from California. He knew when I stood up before the great crowd of mining engineers—and they were half women—and somebody had been telling the story of Adam and the apple; I said that I considered that man Adam the damnedest coward that ever was born on the face of the earth, because, when the Lord came around, Adam said, "The woman did tempt me and I did eat." I would have liked to have been there about that time with an old-fashioned shot-gun. "The woman did tempt me"—what do you say, ladies? Wasn't he a cur? They all nod their heads.

This is a city that I love. I have been in it for more than 50 years. I have been associated with some of the men that have done great work in the City of Pittsburgh. I wish to pay a tribute right here to one of those pioneers, as that dear fellow, your Chairman, has been telling us in the letters that he read. I want to pay a tribute to the name of William Thaw, one of the first men that appreciated scientific work in the City of Pittsburgh.

Away back in 1859 the citizens of Pittsburgh got together, a few of them, and raised money for an observatory up on the hill above us. William Thaw was one of its first directors. The first director of that observatory was so proud of his telescope that he would not even let the Board of Trustees look in it without previous arrangement.

However, in 1867, Professor Samuel Pierpont Langley came to the observatory, and—what many of you do not know—there established the first standard time system on a permanent basis—the first

accurate time system that was established in the United States of America, or in any other country, for that matter.

The Harvard Observatory and the United States Naval Observatory had sent out a few desultory messages of the time by the stars, but Langley was the first to establish it; and before a year had passed 5 700 miles of railways—and that was a great many for those days—had the time signal sent out to their stations; and to this day the Allegheny Observatory stands, with its record of accurate time, better perhaps than any other place in the United States, although some of the observatories keep it very accurately—the average error for last year was $\frac{32}{100}$ of a second—close enough for you to set your watch. For 1914 the average was $\frac{22}{100}$ of a second, and we worried a good deal about that $\frac{10}{100}$ of a second.

It was here that Langley began his studies on the sun, and gave to the world probably one of the most unique studies and determinations that have ever been made, that is, he found the reason why you and I can live upon this earth; why the flowers can bloom; why the birds can sing; and the reason why life may be possible upon any other planet in this great universe of God's creation; and I would like to tell you, because you have been talking about aviation, I would like to tell you that one of the saddest half hours of my life was when my dear friend Langley failed in that flight down on the Potomac, and the word was sent out "Langley's machine a failure." When he talked to me at the Smithsonian Institution about his failure, he said "Mr. 'Brazier' "—he always called me 'Brazier'—"my lifework is a failure." I said to him, "Langley, if you had done nothing more than your memorable work to prove the reason and to give us the facts why life is possible on the earth, you have done enough for one man"; but I could not console him, and shortly afterward he took the fatal stroke that ended his dear life, because a wicked newspaper man, who had a grudge against him, sent out that unkind message.

Gentlemen—ladies first—I was with him in all those early researches and also in his work in aviation; and I shall not forget when I received a letter from that magnificent man, Helmholtz, who had gone over the research work of Langley, with duplicate apparatus we had made for him. In that letter Helmholtz said "My dear Mr. Brashear, I have gone over Langley's whole work in relation to the life history of the earth, and I cannot find a single flaw in it"; and some day, when your friend who stands before you—I won't be here—but when the little box that lies in the corner stone of the work-shop on the hill is uncovered, that letter of Helmholtz will be found there. I don't know whether Langley knows anything about it, on the other side, but I think he does, his work had been done so well, and so useful was the record that he made on Observatory Hill in Pittsburgh.

Then Keeler came along. It was he who solved the problem of the motions of the nebulous bodies in the heavens, and gave to the world a physical solution of the character of the rings of Saturn. Laplace had worked it out mathematically, but the solution was not satisfactory, and finally Maxwell came along and proved mathematically that the rings were composed of discrete particles, like meteoric bodies, but it remained for Keeler to solve the problem, and that was done on Observatory Hill above our city.

And you engineers know of the work of that magnificent man, George Westinghouse, what was done in this, our city, and how his work contributed to human knowledge and human betterment, the prophetic and actual saving of untold thousands of American lives.

Friend Davison, I have always liked the name of your Society. There is something back of it. The Civil Engineer puts into his work something that has a human touch that none of the rest seem to have—civil engineers—God bless you!—that is the work that counts in our lifework. I do not care if you build great structures, that you construct the great buildings and bridges that you do, if you have not the word "civil" back of you, you are not "worth a continental." It is that element that comes into the lives of busy men and makes them great; you must have that element; and I hope that you are every one civil to one another, civil to the ladies—you could not help but be that, for, if you were not, your fellow members would kick you out of the community, and right they would be.

I have had a long experience in this old round world, and in that experience of more than 45 years associated with devotees of science, I have known 180 of the greatest investigators in the world. Two-thirds of them are in heaven now. In the best of these men I have found that element of civility, of kindness, of helpfulness, that counts for a great deal in life's work; indeed, in my humble opinion, no man can be great unless these factors are a part of his make-up.

I do not know whether they are building bridges, studying the stars, or laying out railroads there or not, just so long as they are there, and they will be well taken care of I believe when they get there. I have in my possession a most interesting letter from my dear old friend Prebendary Webb, a great astronomer, a good pious man, an Episcopal minister. We had been studying a crater plain on the moon, where we thought volcanoes were still active—Burtt, Webb, and about twenty others were among the students. Before the work was done, Burtt died, and Webb wrote me: "My dear Brashear, our friend Burtt has gone over to the other side, but I am sure that in going to heaven, if he had his way, he would stop by way of the moon." I would like to stop that way too, although it is an awfully

cold place, and not a very good place for engineers, or anybody else, for that matter.

How can we differentiate the wonderful work of the scientist with the engineering progress that has been made in more than 50 years. When I look back at what has been done in engineering science, it is wonderful, indeed. Why, bless you, my old-time friend Quincy told me that when he was on the Baltimore Railroad, in the first years of its operation, the trains stopped when it got dark, and when it grew light again they started up. There is nothing like that nowadays, gentlemen.

Two years ago, down in Los Angeles, I got into a flying machine, and went up, and up, and up. As we got away above that beautiful St. Gabriel Valley, I thought, "What hath man wrought," as well as, "What hath God wrought?" and my one wish, when I was sailing around in that pure, clear atmosphere, up there, was that Langley had been sitting by my side. There we were flying nearly 3 000 ft. above the plain, and I was as "happy as a big sunflower," only I wished that Langley had been with me.

These things have all come since my début into this world, and they have all been so closely associated with the advancement of every form of engineering that I do not see how you are going to separate them.

I was at a wonderful meeting of scientific men in Terre Hauté, 30 years ago, when they had a gathering of the American Association for the Advancement of Science, and old Dick Thompson, who was Secretary of the Navy under Garfield or some other President whom I cannot now remember, was asked to make a speech. Here is his story: "I don't know what I can tell you scientific men that will be greatly interesting to you, but I will tell you of my association with the electrical telegraph." Then he told us the story of how, in 1844, he was a Member of Congress from that district in Indiana, with two other men who were in Congress from his State. He said:

"We had to ride horseback and stage coach, and when we got to Ohio, where there happened to be a canal, we took passage for part of our journey. Reaching Cumberland, got into a little railroad train and were taken to Philadelphia; and then to New York, for we wanted to see the great city.

"A Member of Congress came across the hallway and said, 'Thompson, there is a man here in New York by the name of Morse, who has an instrument he calls the electric telegraph, and says that he can send a message from Washington to Baltimore in less than two seconds. He wants to ask a subsidy of $25 000 from Congress to put up the line.'

"I went over the next day. There were several gentlemen standing around the machine. He was tapping on it, and there was a little white ribbon of paper came out, marked with dots and dashes. I could not see very well, but when the gentlemen were gone, I was introduced to Mr. Morse who said to me, 'Mr. Thompson, I want to explain this machine to you.' He told me he had 10 miles of wire through the house, and said, 'I can send a message instantaneously, for you see when I put down my key, the message comes down the wire.' He then said, 'Will you ask me a question, and I will try to answer it?' James K. Polk and Henry Clay were then running for President. Thompson said, 'Do you know what I asked him?' I asked him who would be the next President of the United States. He began tapping the key and at the same time dots and dashes came out on the little ribbon. He picked it up and read to me, 'Henry Clay.' Gentlemen, do you know what I said? 'I don't know a damned thing about your machine, but I like its politics, and I will vote for you.'"

Well, the politics was all right. He voted for the subsidy and Mr. Thompson told us that at the next election he got through by the skin of his teeth, but his colleague was defeated for wasting the public money. Think of it. Now, what could you civil engineers do without the telegraph to-day?

The other day I was down in Washington. I took the receiver of a telephone and put it to my ear. I heard the ticking of a clock 500 miles away. I was in New York on a Sunday afternoon, the 24th of January a year ago, with my friend Alexander Graham Bell, and Mr. Carty, the Engineer of the American Bell Telephone Company. We heard messages across our good country from the Pacific Coast. We listened to Mr. Watson's voice, but it did not carry well. Watson was the first man to hear Mr. Bell's voice over the telephone. However, when Mr. Moore, President of the Panama-Pacific Exposition spoke in the telephone, I heard it almost as plainly as if he were speaking from a local station. And then Mr. Carty told us he would put up a replica of the original apparatus made by Watson for Bell, and said to me: "You go in the other room and we will see what we can get from Omaha and back again?" Dr. Bell talked to me and said, "Brashear, do you hear me?" and over that 3 000 miles of wire, over to Omaha and back again, I heard Bell's voice clearly and answered it, to his delight. There was no relay at Omaha.

When I was a guest of my friend Carty on the Pacific Coast last year, he took me to a private room of the Telephone Company, and I heard a message from New York; and then a megaphone on the telephone at Atlantic City enabled me to hear the dashing of the waves upon the Atlantic Coast, while I was listening out on the

Pacific Coast. What would the civil engineer do without the telephone to-day?

A German for the first time was asked to listen at the telephone, when he heard that his wife was at the other end, at a friend's house. Just as he picked up the telephone and his wife came to it, there was a flash of lightning that knocked him down, and he said "That's her; I know her voice."

There are some of us who may think that pure science and engineering do not have much in common, no interlocking places. Ask my friend Smith, of our University, whom I see in the audience, why he is interested in everything of a scientific character. He is Professor of Engineering at our University; he is dabbling in scientific things all the while.

I was a guest at the meeting of the National Association of Scientific men at Washington about three weeks ago—they are the great moguls and the House of Lords of our scientific men—and had the pleasure of speaking to them about our wonderful National Engineering Societies, of which I believe the Civil Engineers have the greatest number of members and some of the most splendid men who have made this country what it is. I asked them if they would not join forces with these societies. There is no doubt we will get all the National Associations to join forces with us. The thing is coming, and I am here to appeal to you Civil Engineers to hasten the day when there shall be no line of demarcation between applied science, between pure science and engineering. Indeed, engineering is to-day on a higher plane of science than ever before, and the day of empiricism is passed forever. You cannot do anything nowadays without a knowledge of science. You do not do things empirically when you build a bridge. No more guesses at the depth of the bridge girder, or at the strength of the ties. Would you, my friend Taylor, lay out a railway without a little knowledge of the use of the transit? I do not think you would do as the sailor did when the captain left him in charge of the helm, saying, "I want you to keep the ship on that star". When the captain came back from his supper he found that the ship was turned around a number of points. "Didn't I tell you to keep your ship on the star?" The sailor replied, "Captain, I passed that damned star long ago." Taylor does not do things like that. He keeps that old transit of his pointed in the right place.

I have for many years been interested in science; I love it for its own sake. So I want you to get at least a smattering of the sciences outside of that which relates purely to civil engineering. Do you think that it makes this carnation that is colored a very beautiful pink any the less beautiful because we happen to know the reason why it is so? Do you think, when I look at a lovely rose, that it is any the

less beautiful because I know it sends out certain rays of light to that wonderful structure, the human eye, and makes us see the rose so beautiful? Do you think it is less wonderful when a blind man goes through the conservatory, and smells the wonderful fragrance of the rose, and tells us of its wonderful structure by the delicate touch of his sensitive finger tips? There is beauty in everything. You know the words of the poet Wordsworth:

"A primrose by a river's brim
A yellow primrose was to him,
And it was nothing more."

I see beauty in the pebbles they haul in the wagons along the streets to fix the pavements. I see beauty in the cement they mix it with. My friend Dr. King told me that the Indians in the North, when they went to see the wonderful sight of the eclipse, saw nothing so wonderful in the eclipse as when they put the water, "dust", and sand together and made solid stone out of it.

The best beauty of all is this civility, is this friendship, is this affection. You shall find it here in the City of Pittsburgh. The other day at a meeting somebody said, "Whoever loves Uncle John, put up his hands", and every woman in the whole place put her hand up. Don't you think that is awfully nice? Sure it is.

You show helpful affection when you do something for the other fellow. Do not wait for him to do it for you. Do it first. I would like to tell you something of the things we have had done for us in the great City of Pittsburgh, but I believe a good part of it is in our friendship, and we are going to show it to you here.

I don't care whether the Mayor was here to welcome you to-day, or whether you may see him to-morrow and say, "We are going to get another mayor next year", or tell him you want him. We do not care about that. We want you to enjoy yourselves in our beautiful city, in our beautiful park, in our beautiful observatory, in all our beautiful surroundings; and when you see our wonderful mills and factories, carry away the memory that here in Pittsburgh there are some human hearts that beat in sympathy with their fellows, and hope to get them to Heaven and give them a helping hand to get there.

The Chairman.—There may be a reluctance (from the large number of regrets that were sent by the 75ers) to test repeatedly the hospitality of Pittsburgh, but I am pleased to say that of the 75ers, there are a few for whom this city has no terrors; I take great pleasure in introducing one of them, Mr. S. M. Gray, of Providence, R. I.

S. M. Gray, M. Am. Soc. C. E.—Mr. Chairman and Gentlemen of the American Society of Civil Engineers and Ladies, I was surprised when Mr. Davison wrote me that it was 41 years ago since I attended a Convention of the American Society of Civil Engineers in Pitts-

burgh. I well remember it; I well remember the pleasure of it; and I can only say that I hope to be here for 41 years to come, in 1957.

THE CHAIRMAN.—Mr. Gray is not alone among those of our former guests. I take additional pleasure in introducing Mr. Clemens Herschel, who, regardless of his youthful appearance, claims that he was here 41 years ago.

CLEMENS HERSCHEL, PRESIDENT, AM. SOC. C. E.—Ladies, Guests, and Fellow-Members: You have probably noticed, all of you, what good work the Committee of Reception in Pittsburgh is doing for us. Well, in their wisdom, and having seen fit—this being the "City of 57 Varieties"—to call on me, on one such as I, to speak in behalf of those who were here 41 years ago. I will only say that we had a most delightful time then, and I do not question for a moment but that we shall repeat it.

At that time the oil industry was just beginning, and, as one of the sights of the day, they took us up into the mountains somewhere near here, and showed us a pipe line, 1½ in. in diameter, through which oil was pumped about 300 or 400 ft., possibly farther. We saw the Lucy Furnace, supposed then to be the biggest thing out. Andrew Carnegie was there to show it to us; and, from what our Chairman of the Reception Committee has said, you know what progress has been made since then; and what I have been describing was the beginning of some of that progress. I need not expatiate upon it. I am very happy to give my little tribute to 41 years ago.

THE CHAIRMAN.—Your Local Committee has undertaken to place before you in a very simple way the various events of the Convention. The programmes were very late in being delivered at the hotel, but we hope that you will secure copies of them at once, if you do not already have them. Please study them carefully, and indicate at the Information Booth the excursions on which you wish to go.

I want to call particular attention to the trip for the ladies this afternoon. That will occur at 2 o'clock, and the arrangements are in charge of a committee headed by Mr. E. K. Morse as Chairman; also to the dinner dance of this evening.

We hope that you will all be present and enjoy yourselves. The committee in charge of the latter affair is under the leadership of Mr. Khuen. I need not mention the remainder of the programme, as it is self-explanatory.

The time has now come when the President of our Society shall deliver the Annual Address. I, therefore, take occasion again to introduce to you Mr. Clemens Herschel, President of the American Society of Civil Engineers.

The President, Clemens Herschel, then delivered the Annual Address.*

* See page 835 of Papers and Discussions.

The Chairman.—I have been asked to request you all at once to secure your tickets for the dinner dance this evening and for the boat excursion to-morrow, so that the committees in charge of these affairs shall be fully informed of the number for which they must provide. This suggestion is equally important in connection with the automobile trip for Friday. So, at the adjournment of this meeting, those who have not already made their arrangements should go to the Registration Room and attend to these matters.

This meeting now stands adjourned, and the Business Meeting of the Society will convene at 2 o'clock in this room.

SECOND SESSION, BUSINESS MEETING.

Tuesday, June 27th, 1916.—The meeting was called to order at 2 p. m.; President Clemens Herschel in the chair; Charles Warren Hunt, Secretary; and present, also, about 100 members.

The President.—I call this meeting to order. The first subject put down for discussion is the time and place for holding the Forty-ninth Annual Convention. What have you, Mr. Secretary, on that subject.

The Secretary.—Mr. President, the first thing to report is a summary of the suggestions that have been received as to the time and place for holding the Annual Convention of 1917.

Report of the Secretary on Suggestions as to Time and Place For Holding Annual Convention, 1917

"As to place:

"Total number of suggestions received, 443.

Chicago, Ill	60	Washington, D. C	9
Detroit, Mich	52	Buffalo, N. Y	7
Boston, Mass	44	Los Angeles, Cal	7
New York City	23	Minneapolis, Minn	6
Denver, Colo	17	Philadelphia, Pa	6
Kansas City, Mo	15	Salt Lake City, Utah	6
St. Louis, Mo	15	Seattle, Wash	6
Atlantic City, N. J	13	Asheville, N. C	5
Cleveland, Ohio	11	Dallas, Tex	5
Milwaukee, Wis	11	Jacksonville, Fla	5
Cincinnati, Ohio	10	San Francisco, Cal	5
Atlanta, Ga	9	Saratoga Springs, N. Y	5
New Orleans La	9		

"The following received 4 votes: Portland, Ore.

"The following received 3 votes each: Birmingham, Ala., Duluth, Minn., Louisville, Ky., Niagara Falls, N. Y., Omaha, Nebr., Portland, Me., St. Paul, Minn., Spokane, Wash.

"The following received 2 votes each: Baltimore, Md., Butte, Mont., Galveston, Tex., Havana, Cuba, Mackinac Island, Mich., Plattsburg, N. Y., Roanoke, Va., Rochester, N. Y.

"The following received 1 vote each: Alexandria Bay, N. Y., Burlington, Vt., Buenos Aires, Argentine Republic, Calgary, Alberta, Canada, Cape May, N. J., Cooperstown, N. Y., Greenbrier, W. Va., Harrisburg, Pa., Honolulu, Hawaii, Hot Springs, Va., Indianapolis, Ind., Ithaca, N. Y., Lake George, N. Y., Mackinaw, Montgomery, Ala., Montreal, Que., Canada, Newark, N. J., New London, Conn., Panama City, Panama, Pittsburgh, Pa., Quebec, Que., Canada, Quebec Bridge, Richmond, Va., San Diego, Cal., San Jose, Costa Rica, San Juan, Porto Rico, Sault Ste. Marie, Mich., Savannah, Ga., Syracuse, N. Y., Toronto, Ont., Canada, Vicksburg, Miss., White Sulphur Springs, Winnipeg, Man., Canada, Some point in Florida, on Chartered Steamer, Buffalo to Duluth, Steamer on Great Lakes, Some Summer Resort, Rotation by Director Districts.

"Suggestions as to time:

"Total number of suggestions received, 390.

February	6	July	31
March	2	August	7
April	8	September	11
May	26	October	5
June	259	November	3

January or February	1	October or November	2
April or May	2	Early Summer	2
May or June	2	Winter	2
May or October	1	Annual Rose Festival (In connection with Portland, Ore., as the place)	1
June or July	11	Some summer month	1
June, July, or August	1	Any time	1
June or September	1	Fair weather	1
June or October	1		
July, August, or September	1		
September or October	1		

"The Secretary also has invitations from the Chicago Association of Commerce, The Columbus Conventions and Publicity Association, the Conventions Committee of the New Haven Chamber of Commerce, the Publicity and Conventions Bureau, Portland, Ore., Chamber of Commerce, the Toledo Convention and Tourist Bureau, and from Edward B. Temple, President of the Philadelphia Association of Members of the Society, enclosing letters from the Mayor and from the Philadelphia Chamber of Commerce, all inviting the Society to hold its next Annual Convention in their cities.

"Respectfully submitted,

"CHAS. WARREN HUNT,

"Secretary."

George F. Swain, Past-President, Am. Soc. C. E.—I move that the time and place for holding the next Convention be referred to the Board of Direction with power.

(Motion seconded.)

The Secretary.—Mr. President, before that motion is put, I think it might be well to inform the meeting that the Society is now divided into 13 districts, 12 of which are non-resident, and that a committee of the Board of Direction has been appointed for the purpose of establishing a rotation between those districts, so that the Conventions of the Society will be held automatically, first in one and then in another section of the country; and the scheme is, that when that order is established, the members residing in that particular district shall simply be asked where in that district they want the Convention held.

The President.—You have heard the motion. Are you ready for the question? All in favor of the motion to refer this matter of the time and place of holding the Annual Convention to the Board of Direction, please say "aye"; contrary-minded, "no". It is a vote.

(Motion carried.)

The President.—The next business is Reports of Special Committees. Are there any Chairmen of Special Committees here who want to report?

The Secretary.—Mr. President, the only report that was expected, so far as I know, was that of the Special Committee on Concrete and Reinforced Concrete. The instructions to that Committee were to present a final report on July 1st, 1916.

The President.—Is there any one here from that Committee?

J. Vipond Davies, M. Am. Soc. C. E.—I would like to move, Mr. President, the discharge of the Special Committee on Concrete and Reinforced Concrete.

In doing so, I wish to make an explanation to the membership.

Over a year ago, when I became a member of the Board of Direction, the Board was treated by some of the various Special Committees as though the Board of Direction did not exist.

The Board asked for the presentation of budgets by the various Special Committees, in order to obtain a knowledge of what was going to be spent and of what the duties and obligations of the Society might be in relation to these Special Committees.

The majority of these Special Committees are doing splendid work; however, at the end of the year it became obvious that, despite the efforts of the Board, these Committees were running on in their own way and manner. The Board, therefore, appointed a sub-committee of its own members, of which I was appointed Chairman with Mr. Lincoln Bush and Mr. Virgil G. Bogue, to study and consider the work of the various Special Committees. Thereupon, I communicated with

each Special Committee and requested information from each as to what work it intended to do, when it intended or contemplated completing its work, what budget appropriations should be made for its work, and, generally, what its plan of operations was to be.

In the early part of this year I received from the various Special Committees certain replies. The Special Committee on Concrete and Reinforced Concrete stated that it expected to make a final report by July 1st, that it had bills outstanding of more than $3 000 unpaid, and that it required for the current year expenditures of $675. I inquired of this particular Committee what was meant by this unpaid obligation and was told that it was the salary of its Secretary, a Member of this Society, and other disbursements that had never been authorized by the Board of Direction, and which the Board of Direction has since declined to recognize.

The Board appropriated $675 for the work of this Committee for the current year, with the definite instructions, following the agreement of the Special Committee, that it would complete its work and report to this meeting of the Society, and by this meeting of the Society the work of that Committee would be terminated.

It was fully expected by the Board that the report of this Committee would be presented at this meeting and no such report is forthcoming. We have been recently criticized in the engineering press for the work of these committees, and are accused of allowing them to go to sleep. This Committee was organized in 1903, and has been existing for 13 years. Some 7 years ago—6 years after its original formation—it presented a report which was a divided report, the minority report being signed by four members of the ten who then formed the Committee. Since then, as far as I know, this Committee has not reported.

The cost to the Society for the various Special Committees has been growing by leaps and bounds, from $316.93 in 1912 to $10 188.24 in 1915, and the Society cannot afford to allow these expenditures to go on in this way.

At the beginning of the current year the Board of Direction, after careful consideration of the money available for the work of the Special Committees, appropriated an amount of $5 000 for the aggregate work of the various Committees for the current year.

The Board recognizes that the work of these Special Committees is of vital importance to the best interests of the Society, but at the same time feels that it is necessary to make sure that the expenditure of the Society's money on these matters should be limited to some definite sum in each year, and that each Committee should present its report within a reasonable period after the date of its appointment.

This particular Special Committee was instructed that printing of

reports was to be done through the regular channels of the Society. Instead thereof, this Committee has proceeded individually and personally to order the printing of progress matter from the printers for a sum, which we are advised by the printers, as it has not come officially to us, of $3 000, which the Board has not appropriated and which there is, apparently, no reason why it should appropriate; and, so far as we can ascertain, this printing is for a progress report for use of members of the Committee, but neither the Board, nor this meeting of the Society, has received advice as to the status of this report.

The work of this printing has been reduced by the printers, as a quotation to the Society, to the sum of $1 500.

If any private corporation or private individuals carried on their business in this way, the services of these employees would soon be terminated. I, therefore, move, without any feeling in this matter, without any desire to prevent a proper discharge of the duties and work of this Committee, but in the interests of this Society, the discharge of this Committee at this time.

(Motion duly seconded.)

The President.—You have heard the motion, which has been seconded. Are there any remarks?

Mr. Swain.—Mr. President, since Mr. Davies spoke, and the motion was made, a good many members have come in, and I would like to ask, before the vote is taken, if any member of that Committee is present.

The President.—Are there any members of the Special Committee on Concrete and Reinforced Concrete present?

Arthur N. Talbot, M. Am. Soc. C. E.—I am sorry I did not get in early enough to hear more than the last words of the speaker. I am a member of that Committee. I have not known of any question of the conduct of the work of the Committee. I have been told that a letter has been sent to the Chairman of the Committee to the effect that the Board of Direction had requested the Committee to complete its work by July 1st.

The Committee has held six meetings since last October (twelve sessions), at which constructive work has been done, and there have been many meetings of sub-committees. The members of these sub-committees have given considerable time and also money for their expenses in doing work bearing on the final report of the Committee.

I do not know about the expenditures for printing. The printing which has been done, so far as I am aware, is the putting of the report in type in its preliminary form, so that the members might have it before them in clear form—a method which was quite necessary in a report of this character, which is not merely descriptive, but contains matter in which slight changes and differences in wording make a considerable difference in meaning.

This Committee has done a good deal of work throughout its life. It was organized in 1904. It has made two reports; and I think it is well established that the reports of this Committee have done a very great deal toward shaping the practice of reinforced concrete in this country, and have had a great influence, and are recognized as being works of value. I am very much astonished to hear that a motion should be made to have this Committee discharged. It seems to me that to pass this would be an injustice to the Committee, and that it would be done only without a knowledge of the circumstances connected with its work.

J. N. Chester, M. Am. Soc. C. E.—I heard only the last remarks of the former speaker. I am not familiar in any detail with the work that this Committee has been doing, nor do I know in any way what the product will be if the report is printed; but I believe that the personnel on that Committee assures us of something that is worth, not only the appropriation asked for, but our while to peruse and study when it comes into our hands.

There are few engineers who are not familiar with the extensive work done by Professor Talbot in the laboratories of the University of Illinois, and the value of its pamphlets and bulletins to the engineer; and for that reason let me implore that no such action as contemplated by Mr. Davies be taken. It is not only an insult to the Committee, but it is a disgrace to the Society to promulgate such a thing at a meeting like this.

Mr. Talbot.—May I say one word more that I intended to say when I was on my feet? A meeting of the Committee has been called at Atlantic City on Friday of this week, the 30th of June. It is expected that the work of the Committee is in such shape that it can be completed at that meeting. It has been the purpose of the Committee since last fall, to have its work completed by the summer.

It may be, of course, that some new discussion may arise that will not permit the work to be completed at that meeting, but it is expected that the report will be finally finished then.

John A. Ferguson, Assoc. M. Am. Soc. C. E.—Mr. President and fellow-members, what I have to say will be simple and brief. I wish to speak of the work of this Committee. It has been organized as the parent committee, associated with committees of other associations. These associated committees have not as yet presented their reports to their societies. I understand that they will do so in a very short time. The American Society for Testing Materials is to meet for this purpose on Friday of this week. It would appear that it is not logical for the parent committee to make its report until the sub-committees have made theirs to the Committee.

I think that to discharge this, the parent committee, before those affiliated with it have reported would be a breach of faith with them,

and it would put our own Society in the light of being unable to cope with its internal affairs. I don't know all about the working of the Board of Direction or of its authority over the committees, but it would appear to me that this Committee would be subject to the will of the Society. Should there have been any breach of the will of the Society or of the Board of Direction, I would think that it would be much wiser to deal directly with any person so offending, and leave the Committee and the members of the Committee who have not offended in their original standing with the parent Society and the other committees of the Joint Committee.

I know that this Committee has been working upon many things for which the engineering world has been waiting. I know that it has as members very good and eminent men well qualified to finish this work.

I am myself holding back the preparation of some ordinances of which this city is badly in need until I may know what is to be the finding of this Committee. My situation becomes more acute through every day's delay. As a Member of this Society, I am entitled to request that the stress that exists throughout the country in these matters be adjusted as quickly as possible, by a report of the Committee, and that the matter be not delayed by the discharge of the Committee.

Mr. Talbot, the only one of the Committee who is here, is, I know, strong, upright, and capable, and one of the best engineers of the country, and he will not delay this matter any more than it is necessary in order to get at the bottom of the matter. I would suggest that such action as is taken here support the work of the men of such caliber as his. And remember that every single day spells some advance in this art, and it is a very difficult matter to decide just what it is best to do in this whole problem. Thus it will be realized how hard it is to find a stopping place so as to make a report that will do what we want it to do.

The President.—Any further remarks?

Mr. Davies.—I would like to say one word that arises out of the last speaker's remarks. I, also, am a member of the American Society for Testing Materials. One of the troubles in the present situation appears to me to rest in, what I believe to be, the fact that the interests of the American Society of Civil Engineers are subordinate to other committees co-operating with it in this work.

If we cannot obtain a report from the Special Committee on Concrete and Reinforced Concrete now—13 years after the date of its appointment—the only way to defend the Board of Direction is to put the situation up to the membership, as I am doing now.

Personally, I do not care which way you vote in this matter, but I do want to put on you, the members of our Society, the onus of decid-

ing whether you wish this Committee to fulfill or ignore the obligations which it took upon itself 13 years ago, to finish its investigations and report to this Society.

Mr. Talbot.—I, also, am a member of the American Society for Testing Materials, a very excellent society, a society which is doing a strong work. In some respects, I wish the committee work of the American Society of Civil Engineers was as strong, active, and vigorous as the committee work of that society. The representatives of the American Society for Testing Materials on the Joint Committee on Concrete and Reinforced Concrete have not been unduly active; they are not more active than the membership from the American Society of Civil Engineers. As a matter of fact, it is the feeling of the officers of the American Society for Testing Materials that much of the work of this Committee is outside of the province of the American Society for Testing Materials, and though they have kept their connection with the work, it has been felt that the part in which that society was interested is connected with the materials, the concrete as concrete, and the materials which go to make up the concrete, rather than with features relating to building ordinances, the calculations of stresses, or the requirements of design.

Mr. Swain.—I understand the situation is this. The Board of Direction has requested this Committee to submit its final report. Professor Talbot says it was requested to submit its final report by the end of the month.

Mr. Talbot.—So I am informed.

Mr. Swain.—The Committee contemplates complying with the request, and expects to have its report completed and submitted by the end of this month, having its last meeting on the 30th. Under those circumstances it does not seem to me that it would be quite proper for this Society to discharge the Committee at this time; and it seems to me that the best form of the motion would be, that upon the receipt of the report of the Committee, which is expected within a few days, the Committee be discharged.

Mr. Davies.—I accept that if Professor Swain will set some day as a date for the termination of that period.

Mr. Swain.—I understand that the Committee has been asked by the Board to submit its final report by the end of this month, and it expects to submit it by the end of the month.

Mr. Davies.—Then I am perfectly willing to accept the amendment.

The President.—You have heard the motion as it is amended——

A. Marston, M. Am. Soc. C. E.—I think that we wish to uphold the authority of the Board of Direction, but that we do not wish to throw away the very excellent work which this Committee has been performing.

I am sorry to hear the criticism of the American Society for Testing Materials. That Society has had similar troubles in connection with the work of this same Committee; and the Board of Direction is not alone in experiencing difficulties of the kind described to-day. I think the difficulties are due, not to the membership of the Committee as a whole, but to certain members of the Committee. In spite of the difficulties mentioned, the report of the Committee should certainly be received, printed, and circulated widely.

Mr. Talbot.—If I may have another word, I submit that it is not fair to a Committee, which has given 12 years of time and which has done work through most of those 12 years, to discharge the Committee immediately upon the receipt of its report, without giving the Committee a chance to present it, without giving a chance to defend it, in case there is a minority report, as it seems quite possible there may be, from some member of the Joint Committee not a member of the Special Committee of the American Society of Civil Engineers.

If there is something connected with the financial management which is open to question (and I feel quite certain that the statements made here respecting the cost of printing the report are in error), then let the Board of Direction take that up, but do not bring it before the Society in Annual Convention, where there is little opportunity to know the status or to discuss the situation.

I feel that to pass such a motion as this would be, to use a common expression, a slam at the Committee and also at all Special Committees of the Society.

Gardner S. Williams, M. Am. Soc. C. E.—It seems to me that we are confronted with an awkward and an unfortunate situation. This Committee was created before the present regulations of the Board regarding committees were promulgated. It was created by action of the Society, and is only a creature of the Board in so far as the Board has the general direction of the financial matters of the Society. If I remember the conditions under which it was created, it could only be dismissed by a meeting of the Society, either at this time or at the Annual Business Meeting. Am I not correct, Mr. Secretary?

The Secretary.—I do not know. I believe that the original action was by the Society in Annual Meeting and that subsequently the Committee was appointed by the Board of Direction.

Mr. Williams.—But pursuant to the act of the Society. Our Constitution is not altogether definite in these matters; but there is fairly good ground, at least, for the position that if that Committee is to be dismissed, it must be dismissed by the Society and not by the Board of Direction.

Now, we all know more or less of the personnel of that Committee. We know that it has upon it some of the most eminent men in the

Profession, in the particular branch involved, men against whom none of us could raise a finger. It is a fact, however, as I know from my own personal observation, that the Committee has not given to the Board of Direction the information which the Board was entitled to ask or entitled to receive. That cannot be denied by any member of the Committee who is conversant with the facts. The Board of Direction—I am not a member of it now, gentlemen—had no alternative but to come to you and to ask you to take this matter in hand. Now, the Committee says it is going to be good, and I hope it will be; I believe it will be; but I think that after this little airing of the situation it would be better if we were to substitute for the motions before the Society something to the effect that this Committee be given until the Annual Meeting in January to finish its report, and that at that time it be discharged.

I would offer that as a substitute for the motion that is now pending.

The President.—Are there any further remarks?

G. G. Underhill, Assoc. M. Am. Soc. C. E.—The situation before the Society is that it would like to get this report, and would like to have everything, the treatment of the Committee and the treatment of the Board, satisfactory; and I think that can be attained by a further amendment to the effect that unless the Committee presents its report by the next Annual Meeting that it be discharged. The effect of such action will be that if, at the next Annual Meeting, the report is presented, the Society will then be in a position to accept it, and give the proper thanks to the Committee for its work; but if the Committee during the next 6 months is still delinquent, it will be so in the face of the certain knowledge that at that time it will be discharged. I, accordingly, move to amend the amendment before the meeting to the effect that unless the Special Committee on Concrete and Reinforced Concrete presents its report at the next Annual Meeting, that it be discharged.

Charles F. Loweth, M. Am. Soc. C. E.—I hope the last motion will not prevail. It seems to me that the Committee has had sufficient notice of the action that we take here. I am quite in accord with what Professor Underhill has said. I think that we should give the Committee until the next Annual Meeting to bring in its report, and that if further time is needed at that time, that the Committee can take it. I hope that that amendment will carry.

(Motion duly seconded.)

Henry B. Seaman, M. Am. Soc. C. E.—I think that is the only course which the Society should take, after what has been said here to-day. It gives ample notice; it is not threatening; but it shows the tenor of opinion in the Society. We are impatient to get that valuable report, but we cannot get any report of value on 3 or 4 days' notice.

However, I think 6 months' notice should be sufficient, as I understand that the report is about completed. We can then take whatever action is advisable. I second Mr. Williams' motion.

Mr. Talbot.—As there seems to be no one else here who knows about the work of the Committee, I hope that I may be permitted to say one more word concerning the work of the last two years.

At the meeting of the Committee held in Baltimore, at the Annual Convention two years ago, the Committee decided to make another report, with the expectation that it would be the final report. Considerable matter was formulated before the time of the meeting, which was held in New York last October, and at that meeting it was definitely voted to make the report the final report and to ask the Society that the Committee be discharged.

There was some opposition to this action at the beginning, even from the officers of the American Society of Civil Engineers, because it was stated that with the difficulty in forming a Committee of this kind it would be much better to keep this Committee in existence, and, when a further consideration of the subject was needed, the work could be started again without difficulty, even with a changed personnel of the Committee.

The Committee, however, felt that it was wiser that this Committee should make its report and retire, and then when there is need for further report upon this subject and when further experience and data are available, a new committee may be appointed, with a new personnel, a new point of view, and the new committee would then take up the matter in an entirely new way.

It may be proper to say that, in the last 12 years, practice in reinforced concrete in this country has gone through a great growth and development. It was in a chaotic state in 1904, and the first report, made in 1909, helped to modify practice in design materially and to unify the practice of the country. The second report, made in 1912, was a revision and extension of the first.

The two reports went far toward standardizing methods of calculation, principles of design, limits of working stresses, and details of construction among engineers, building departments, and architects. Although not all the recommendations have been accepted in detail, the reports have had a strong influence on practice, and the principles of the reports have been quite generally accepted. It is hoped that the third report will go still further in giving the recommendations of the Committee on the principles of design for reinforced concrete structures.

A new subject being treated in the final report is the flat slab type of floor construction for heavy building work. To show something of the time required for formulating a report, a draft of a chapter, so-called, on flat slab construction was presented to the members of the

Committee before the October meeting. It was distributed to members of the Committee and to others who were engaged in reinforced concrete design and construction outside of the Committee, and another meeting was held in January, at which there was a wide divergence of opinion expressed as to whether the method and principles proposed were proper. I think you would all be surprised to know how divergent were the views held on the action of the flat slab structure and on the methods which should be followed in its design. An informal meeting of the Committee was held at Chicago in February, at which there were present representatives of several of the leading reinforced concrete construction interests, contractors, designers of so-called systems, and so forth; and they presented their views, offered their objections, and gave their opinions; they also presented data on building construction and tests that took time to be digested. The flat slab report was then modified by the sub-committee in May and discussed, and was presented, modified, and extended at a meeting held about a month ago; and that modified and extended report is one of the matters which will be considered at the meeting at the end of this week.

If a satisfactory formulation of the principles and methods of design for flat slab structures can be agreed to by this Committee, and then finally accepted in fair measure by the country, I think a great step in advance will have been made, and if necessary to accomplish this, a delay of a year, or even of two years, in the completion of the report would be compensated for.

I am not sure that the diversity of views held on some of these matters is appreciated, or the great differences among commercial and building interests which must properly be considered. I do not believe that you understand what differences in view there are, differences among designers as to how a structure acts, differences among various interests, all of which take time in obtaining agreement in action, or there would be no thought of passing a motion such as is proposed here to-day.

John Lundie, M. Am. Soc. C. E.—Mr. President, I understand the present discussion is brought about because of the fact that this Committee is essentially a creature of a Convention or of the Members of the Society, and not appointed by the Board of Direction. Now, why would not this be the proper course: let the Convention turn back its powers of appointment to the Board of Direction. I, therefore, make a motion that this whole matter be turned over to the Board of Direction with power to act.

Mr. Swain.—I would like to ask if Professor Talbot has any motion which he would like to suggest as covering the situation, which he thoroughly understands, as I think we all do, now.

Mr. Davies.—I would like to state to Professor Talbot that if we had had furnished to us such information as he has given, as to the

work of the Committee and the difficulties of the Committee he represents, in arriving at its report, we would probably have felt differently. On February 10th last, I asked the Chairman of this Special Committee what was remaining to be done and how long it would take to complete the work of his Committee. There was at that time no intention or desire to hurry the Committee. The reply then was that it was the intention to issue, by July 1st of this year, a final report. This report has not yet made its appearance, and that is the reason why it has come up in the way it has.

Mr. Talbot.—Allow me to say that I have information from Mr. Worcester, the Chairman of the Committee, that he received from the Chairman of the Committee on Special Committees of the Board of Direction, word to the effect that the report received from the Chairman of the Committee on Concrete and Reinforced Concrete concerning its work was the only one received from any committee of the American Society of Civil Engineers.

Mr. Davies.—That was the budget asking for the appropriation of $675 plus $3 000, which this Committee has expended in the past 3 years and for which the Board had never made appropriation. The expenditure included $2 000 for the Secretary's salary and other expenses.

Mr. Talbot.—I do not anticipate trouble about the budget. The financial statements have been sent out by the Committee to its members.

I wish to say also that the Progress Report of this Committee, made at the Annual Meeting in New York last January, stated that the Committee expected to present its final report this year.

Henry H. Quimby, M. Am. Soc. C. E.—I hope that neither the original motion nor any of the amendments to it will prevail. I think that the subject has been sufficiently aired, and that the most graceful thing will be to take no action upon it here. I think Dr. Talbot's statement ought to be a sufficient explanation of everything that has been done or not done, with the possible exception of the financial matter that Mr. Davies has complained of; and it does seem to me from what I know of the Joint Committee work, although I have nothing to do with the financial part of it, which is being handled by a Sub-committee on Ways and Means, that there must be some misunderstanding. I think we did not ask the American Society of Civil Engineers for $3 675. That amount, in my mind, is about the total that we wanted from all the contributing societies together.

I am one of the representatives of the Testing Materials Society on the Joint Committee. It ought to be well understood here that the Special Committee of this Society is acting with representatives or corresponding committees of four other societies; and I think that the Special Committee of this Society was given express instruction

or authority so to act, whether it was by the Board of Direction or by a Business Meeting of the Society I do not remember. At any rate, their work must necessarily be done together, and it seems to me that it cannot be expected that any unit Committee can reasonably be required under a threat of dismissal to complete its work within a limited time.

Since no other member of the Joint Committee than Dr. Talbot has spoken, I feel as though I ought to say that what he has told of the work of the Joint Committee is a very moderate statement of it, and especially of the work of such of the members of that Committee as represent this Society.

I think that more of the work of the Joint Committee has been done by Dr. Talbot and his associates representing this Society than by the representatives of any other single society on the Joint Committee, and Mr. Davies' charge that this Society is being subordinated to other societies is unwarranted. Also, nearly all the members of the Joint Committee are members of this Society. What Mr. Davies said seems to me a very scant recognition of the work of this Committee. There has been a lot of work done and a lot of expense paid by the members of the Committee, during the 12 years of its existence. Not a year has passed without several meetings, and this year meetings are being held monthly.

The members of the Committee have paid their own railroad fares and hotel bills, and we should not be expected to pay also for typewriting and printing and postage.

I think the least this Convention can do is to accept Professor Talbot's information regarding the work done and to be done as constituting a satisfactory progress report. As he has said, we are programmed to meet at Atlantic City next Friday, 30th inst., and to continue in session until the substance of our final report is definitely determined. This is work that cannot be done in a day. It takes thought and time, because the subject is a large one.

I move, Mr. President, that the matter be laid on the table.

(Motion duly seconded.)

THE PRESIDENT.—There have been a great many motions made; some seconded and some not seconded. I shall put the motion that was last made and seconded, that the subject be laid on the table, unless anybody wishes to make further remarks on that subject.

JOHN C. TRAUTWINE, JR., ASSOC. AM. SOC. C. E.—Mr. President, may an Associate speak on this question?

MR. WILLIAMS.—A motion to lay on the table is not debatable. If we want to talk more let us seek another opportunity.

THE PRESIDENT.—I put the motion to lay on the table. All in favor say "aye"; contrary-minded, "no".

The Chair has no doubt. Unless objection is made the Chair declares the motion carried. It is carried.

Is there a report from any other Special Committee?

Is there any new business to bring before this meeting?

John A. Ockerson, Past-President, Am. Soc. C. E.—In response to the welcome given us this morning, I offer the following:

"We greatly appreciate the cordial welcome extended to us by the City of Pittsburgh through its official representatives; and while the interval between our visits has been a long one, we have watched with interest and pride the rapid development of one of the great industrial centers of the world.

"We congratulate the city particularly on its galaxy of great captains of industry, who have contributed so much to the development and progress of our whole country, and we look for even greater achievements in the future.

"To the local members of our Society, and their associates, one and all, we extend our hearty thanks for the generous provisions made for our entertainment and instruction during the Forty-eighth Annual Convention.

"We trust that we may again have the privilege and pleasure of enjoying the hospitality of this progressive city."

Mr. Williams.—I second that motion.

The President.—You have heard the motion, which is seconded. Are there any remarks? If there are no remarks, I will put the motion. All in favor please say "aye"; contrary-minded, "no". It is a vote.

Is there any further new business to come before this meeting?

Mr. Swain.—On behalf of a Committee of the Board of Direction, composed of Past-President Ockerson, Past-President McDonald, and myself, I beg leave to submit the following resolution with reference to our lamented deceased President:

"*Whereas:* It has pleased the Almighty, in His Infinite Wisdom, to remove from the scene of his earthly labors, Elmer Lawrence Corthell, President of the American Society of Civil Engineers; be it

"*Resolved:* That the members of the Society, in Annual Convention assembled, express their grief at the loss of so distinguished an Engineer and so lovable a Man, and their admiration for his many noble qualities of heart and mind. They are thankful that he was granted a life so long, so fruitful for the Profession and for Mankind; with pride and pleasant memories they testify to his eminence as an engineer, his enthusiasm for the best interests of the Profession, his sterling character as a man, his unswerving loyalty as a friend. With saddened hearts they deplore his loss, and extend their deepest sympathy to the family so heavily bereaved; with trust and faith they resign themselves to the will of Him who doeth all things for the best.

"*Resolved:* That these resolutions be transmitted to his family, and that a copy thereof be spread upon the records of the Society."

I move the adoption of these resolutions.

(Motion duly seconded.)

THE PRESIDENT.—Gentlemen, I suggest that we vote on this by a rising vote. All in favor please rise.

(Motion carried.)

Is there any new business to come before the Society?

WILLIAM N. BROWN, M. AM. SOC. C. E.—Mr. President and Gentlemen of the Society, I want to bring to the attention of the Society a matter that I think of interest to engineers, that is, the matter of Government competition in engineering along certain lines, thus depriving engineers of employment.

I think the members of the Board, personally, have had the matter brought to their attention, and they are taking action. I do not want to say anything, or to ask for any action that would embarrass them, but I think that a discussion of the subject, and bringing it to the attention of the members, might do some good. Perhaps the Secretary could give us some information as to what they are doing.

THE SECRETARY.—The Secretary cannot give very much information. There was a letter received by the Society which complained of interference by at least one of the Government departments or bureaus with the work of the private engineer. That matter was referred to the President of the Society, who has taken it up with that bureau, at least, but nothing definite has been established as yet.

THE PRESIDENT.—Are there any further remarks on that subject? There is no motion before the house. If there is any further new business to come before the Society now is the time to present it.

THE SECRETARY.—I have one or two announcements to make. With regard to the ballots on the question of the proposed movement of the Society Headquarters from 57th Street to 39th Street, for the information of the Membership, and in order to spread it on the minutes of the meeting, I will read the report of the tellers, who canvassed that ballot, addressed to the Board of Direction.*

Mr. President, I have a list of the persons elected by the Board of Direction at its meeting of June 23d and 24th, 1916. There were 10 Members, 29 Associate Members, and 13 Juniors elected, and 18 Associate Members were transferred to the grade of Member and 9 Juniors to the grade of Associate Member. It would be a great pleasure to read those names, sir, if you would like to have it? Shall I read them, sir?

THE PRESIDENT.—If you think proper.

HUNTER MCDONALD, PAST-PRESIDENT, AM. SOC. C. E.—I move that the reading be dispensed with.

(Motion duly seconded and carried.)

THE SECRETARY.—Mr. President, I have the following letter, which I have been asked to read to this meeting:

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* See page 458.

"MAY 6, 1916.

"AMERICAN SOCIETY OF CIVIL ENGINEERS,
"220 West 57th Street,
"New York, N. Y.

"DEAR SIRS: In September of this year there will be held in Philadelphia a lecture course in illuminating engineering which is expected to be of great importance in promoting the lighting art as a whole, and illuminating engineering as a specialty. As this is a matter of far-reaching importance, I take the liberty of enclosing herewith a statement concerning the lecture course, with the request first, that you have an announcement made before the meeting of your Society which I believe will take place during June, and second, that you assist the project by giving some publicity to it in your Society publications.

"Trusting that we may be benefited by your kind co-operation, I am

"Yours very truly,

"PRESTON S. MILLAR,
"Chairman."

Anybody interested may secure from the Secretary a copy of the programme of the course of lectures.

I have, with regret, Mr. Chairman, to announce the death of Charles Hopkins Cartlidge, of Chicago, Ill., elected Member, May 4th, 1904; died June 14th, 1916.

I have no further announcements to make, sir.

THE PRESIDENT.—The Secretary has no further announcements to make, but the Chairman of the Local Committee desires to make an announcement as to the programme.

GEORGE S. DAVISON, M. AM. SOC. C. E.—On behalf of the various sub-committees having charge of the programme, I want to impress on you the importance of immediately signifying your preferences for the excursions of Thursday. At the rear of the hall, or near the door, you will find slips, upon which you may record your choice. This is important, so that the various committees may be able to make such arrangements as may be necessary.

I also want again to request those who want tickets for the excursion to-morrow and the dinner dance, to get them at once; also for the automobile trip on Friday, for which there will be no charge.

The committees in charge of these three events must order luncheon for the parties, and as it is desired to make ample provision, I hope you will assist these committees by attending to the matter at once.

On behalf of the Golf Committee I would say that they have posted a notice termed "Golf Information" in the Registration Room; but the Chairman desires me to speak of the schedules of trains that leave in the morning for the tournament. He suggests that you might break up into parties and not all land at the course at the same time.

He also wishes me to read this paragraph from the notice: "Each player wishing to enter this tournament should place in the hands of the Golf Committee his 18-hole handicap on his home course, also par for the course, and the length of the course."

Mr. Chester, in charge of the "57 varieties" excursion, asks me to say that he must give the Heinz people notice to-morrow morning by 9 o'clock as to how many will be on the trip to the Heinz plant on Thursday. I am mentioning this particularly so that you may communicate this information to the ladies.

The President.—If there is no further business before the meeting, and no further announcements to make, a motion to adjourn is in order. Is there any further business?

The Secretary.—I move that the Board of Direction be requested to frame suitable resolutions of thanks for the courtesies which we will receive, but for which we cannot extend thanks at the present moment.

C. H. Keefer, M. Am. Soc. C. E.—I wish to say, as a Member of the Board of Direction, that I have much pleasure in seconding this resolution.

I am sure that we all feel very much indebted to the Local Committee and the Pittsburgh members generally, for the opportunities they are giving us in meeting here. There are, no doubt, many of our "Brother" engineers who, like myself, are seeing Pittsburgh for the first time. We, I am sure, realize that in many ways it is the "Mecca" where, as "Engineering Pilgrims", we have come to the place of all places that men of our profession want to see at some time or other. There is so much provided for our professional benefit and social entertainment by the Local Committee that I feel sure we will be more than satisfied with the choice of Pittsburgh as a Convention city.

The President.—You have heard the motion. I will repeat it, in the language of the brokers, it is a resolution to return thanks if, when, and as rendered, when the courtesies are rendered. All in favor say "aye"; contrary-minded, "no". It is a vote.

The President.—Mr. Cummings wishes to distribute certain circulars, and that is the reason that the motion to adjourn is held in abeyance.

Allen Hazen, M. Am. Soc. C. E.—Mr. President, I would like to ask what action, if any, has been taken in regard to the Alfred Noble Memorial.

The Secretary.—Mr. President, the Chairman of the Committee on the Alfred Noble Memorial is present, I think. Mr. Bates might say a few words.

Onward Bates, Past-President, Am. Soc. C. E.—I am very glad that that question has been asked, because the Committee has found that work of this sort moves very slowly, and I would not have you think that the Committee is sleeping on it. I shall explain as well as I can the present status of our work, and will be glad to answer any questions about it.

In the first place, the Committee had before it the necessity of procuring a site for the Memorial. I believe I am right in saying that the resolution of the Board of Direction authorizing this Memorial requires that it shall be built in the City of Washington, and it was necessary for us to select a site and to obtain Congressional approval, which was granted some time during the past winter.

In the next place, we had to employ a sculptor. In October last we engaged Mr. Paul Bartlett to prepare preliminary designs for the Memorial. Mr. Bartlett has promised to attend a meeting of the Committee which will be held during this Convention, and will then submit plans and photographs of his models.

We cannot hurry work of this character, and I reckon it is just as well in this case, because the last two years has not been a good time in which to ask contributions from engineers, and we hope for improved conditions from now on. It will be in order, as soon as the Committee can adopt the design, to advise engineers, members of this Society, and others, all who honor the Profession and who loved Alfred Noble, of their privilege to contribute to this Memorial. We will at that time be able to furnish a description of the proposed Memorial and its surroundings, with illustrations showing its character, and will then be ready to receive the money to pay for it.

Now, gentlemen, this is a National Monument, and we do not expect that we shall have to ask for money for its completion. It will be a matter of pleasure and of professional pride for us to contribute to a National Engineering Monument which is dedicated to Alfred Noble, and I am sure that all the money needed will come without effort. We have evidence of this, for some, without waiting to be asked, have already offered handsome contributions. Speaking for myself, this is the Engineers' Monument, for all engineers, young and old, each of whom should have a direct personal share in it, and I feel the same interest in a small contribution from a young man just starting on small salary, as in a large gift from the old engineers who have been exceptionally fortunate in their practice.

I hope the Committee will soon be able to report further progress, and to accompany the report with the statement that the subscription list is open. Now, if there is anything I can add I shall be pleased to do it, or to answer any questions.

THE SECRETARY.—Mr. Bates, as Secretary of the Committee, I would ask you to say a word upon the site that has been selected and approved.

MR. BATES.—I do not know whether I can make it plain to you just where the site is. I do not remember the streets very well. Please correct me if I make a wrong statement. It is on New York Avenue opposite the new Interior Building, which is now under construction. It is in form of a rectangle. I think a good point about this site is that it will have to be graded, trees will have to be moved, and we will have this rectangle block with cross-walks and diagonal walks, with the Memorial in the center, and the shrubbery adjusted for artistic effect. The trees are old, and it is just as well for us to have new trees put in to suit the general arrangement.

The Committee has been fortunate in having as a member Col. Harts, who is Superintendent of Buildings and Grounds, and is also Secretary of the National Fine Arts Commission, to which our plans must be submitted for approval.

A MEMBER.—What form will this memorial take?

MR. BATES.—I am sorry I cannot tell you, because the sculptor has not kept us in touch with what he is doing. We will consider the question of form at the meeting of the Committee which is to be held during this Convention. I may say this, that the Committee is not at present committed to any form.

THE SECRETARY.—I think it might be well to say that the Committee has decided that it shall not be in the form of a statue.

MR. BATES.—I believe it is not to be a picture statue.

THE SECRETARY.—It will be symbolic in some way or other.

HENRY GOLDMARK, M. AM. SOC. C. E.—I think there is no doubt that there has been a great deal of sculpture erected, in both New York and Washington, that is not good, artistically. It would be very desirable, I think, that anything that is built to honor Mr. Noble should be the best of its kind; I, therefore, hope that every effort will be made to get a memorial that will be absolutely of a high order; that there shall be no mistakes made, as there have been with the best of intentions in the case of many monuments, even some quite recently built in our larger cities.

MR. BATES.—I can only say that the Committee is seeking the best professional advice it can get. The Chairman is not an artist himself, but he is accustomed to weighing evidence.

THE SECRETARY.—Mr. President, it is necessary when you put up a monument, not only to have a sculptor but an architect. I can say that the Committee has the advice of the very best talent in both of those lines, and that the slow progress of the Committee is not due

to the fact that it did not want to hurry this matter, but that it could not do it any faster.

The Committee hopes, in a very few months, to place a design before the Profession that will be accepted, and it does not doubt that it will be able to do so.

The President.—As far as the Chairman is informed, the motion to adjourn is now in order.

Mr. Williams.—I move we adjourn.

(Motion duly seconded.)

The President.—It has been moved and seconded that we adjourn. All in favor say "aye": contrary-minded, "no". It is a vote.

FORTY-EIGHTH ANNUAL CONVENTION

EXCURSIONS AND ENTERTAINMENTS

The arrangements were in the hands of the following Local Committee:

George S. Davison, *Chairman*;

J. A. Atwood,	D. W. McNaugher,
Robt. A. Cummings,	Emil Swensson,
Richard Khuen,	E. B. Taylor,
Morris Knowles,	Wm. Glyde Wilkins,

Paul L. Wolfel.

Ladies Fxcursion

Tuesday, June 27th, 1916.—2 P. M.—The visiting ladies were the guests of the Ladies General Committee on a special trolley trip to the East End, and for a general view of the city. The trip was very enjoyable, and was attended by 87 ladies. During the trip the ladies were the guests of Mr. H. J. Heinz at his East End residence, where they were afforded an opportunity to inspect his collection of curios.

Dinner Dance

Tuesday, June 27th.—7 P. M.—A Dinner Dance, attended by 262 Members and guests, was held in the ball room of the William Penn Hotel; dancing was informal.

River Excursion

Wednesday, June 28th.—The day was devoted to a River Excursion. The party left at 9 A. M. by special train from the Pennsylvania Station to Lock No. 4 on the Monongahela River, where it embarked on the Steamer *Sunshine*. Luncheon was served on the steamer, and the trip was made down the river to Pittsburgh. While the steamer was at Lock No. 3, the Chittenden Drum Weir was operated for the benefit of the party, through the courtesy of Col. F. R. Shunk, Corps of Engineers, U. S. A. There was informal dancing on the boat, and 324 persons attended.

Excursions to Industrial Plants

Thursday, June 29th.—Twelve parties were made up to visit the following plants: Carnegie Steel Co., McClintic-Marshall Construction Co., Rankin Plant, Universal Portland Cement Company's plant at Universal, National Tube Co., McKeesport Plant, Armstrong Cork Co., H. J. Heinz Co., U. S. Bureau of Mines and Bureau of Standards, American Bridge Co., Ambridge Plant, Baltimore and Ohio Improvements, 33d Street Elevation, Carnegie School of Technology, Mellon Institute of Industrial Research and Laboratories of the University of

Pittsburgh, and Filtration Plant of the Pittsburgh Water Department. The foregoing works were visited by parties varying in numbers from 9 to 65.

President's Reception and Ball

Thursday, June 29th.—8.30 P. M.—Three hundred and fifty-five Members and guests attended this ball. They were received by President and Mrs. Herschel assisted by other officers of the Society and their wives. The evening was a most enjoyable one, and dancing was kept up until a late hour.

Golf Tournament

Friday, June 30th.—The Golf Tournament was participated in by a number of Members and guests of the Society, and was held at the Oakmont Country Club, which had courteously placed its Course and Club House at the disposal of those in attendance at the Convention. The tournament was an all-day affair, 36 holes being played for four trophies presented by the Local Committee.

Automobile Drive

Friday, June 30th.—10 A. M.—Members and guests not participating in the golf tournament left the William Penn Hotel in special automobiles for a 50-mile drive through the country. The party stopped for luncheon at the Oakmont Country Club, where the golf tournament was being held, and returned to the hotel about 5 P. M. This was a large party, consisting of 253 Members and guests.

Smoker

Friday, June 30th.—8 P. M.—The Engineers' Society of Western Pennsylvania tendered a "Smoker" to the Members of the Society and their guests, in the ball room of the William Penn Hotel. An interesting and amusing entertainment of music and vaudeville was presented, and the evening was a great success. The attendance was 525.

Attendance

The following 323 Members were in attendance. There were also present 191 ladies and others of the families of members.

Adams, W. H.....Detroit, Mich.
Affelder, L. J.....Pittsburgh, Pa.
Africa, J. M....Huntingdon, Pa.
Allen, Kenneth...New York City
Alvord, J. W.......Chicago, Ill.
Ammann, O. H...New York City
Anderson, J. H...Pittsburgh, Pa.
Atkinson, Asher, New Brunswick, N. J.
Atwood, J. A....Pittsburgh, Pa.

Babcock, W. S....New York City
Baker, I. O..........Urbana, Ill.
Baker, J. J.......Johnstown, Pa.
Baldwin, A. S......Chicago, Ill.
Ball, C. B..........Chicago, Ill.
Banks, J. E.......Ambridge, Pa.
Bates, Onward......Chicago, Ill.

Beach, L. H....Cincinnati, Ohio
Beard, V. D.....Pittsburgh, Pa.
Beebe, J. C........Dayton, Ohio
Begg, R. B. H..Blacksburg, Va.
Beggs, G. E....Princeton, N. J.
Bensel, J. A.....New York City
Bigelow, E. M....Pittsburgh, Pa.
Blackford, F. W..Columbus, Ohio
Blickle, H. R....Pittsburgh, Pa.
Blum, L. P......Pittsburgh, Pa.
Boardman, C. S...Buffalo, N. Y.
Bontecou, Daniel, Kansas City, Mo.
Booth, A. A.....Spokane, Wash.
Boyd, W. C......Pittsburgh, Pa.
Brady, S. D....Fairmont, W. Va.
Bringhurst, H. M.Pittsburgh, Pa.
Brower, I. C.......Evanston, Ill.
Brown, N. F.....Pittsburgh, Pa.
Brown, W. N..Washington, D. C.
Brown, W. P....Cleveland, Ohio
Bryant, B. H....New York City
Bryson, Andrew.New Castle, Del.
Buckwalter, H. D., Harrisburg, Pa.
Burden, Morton..Pittsburgh, Pa.
Burns, C. S....Kansas City, Mo.
Bush, H. D......Baltimore, Md.
Bush, Lincoln....New York City
Byers, B. B. F..Pittsburgh, Pa.

Campbell, C. C..Philadelphia, Pa.
Cappelen, F. W., Minneapolis, Minn.
Casani, A. A.....Pittsburgh, Pa.
Case, G. W......Pittsburgh, Pa.
Chandler, E. F.University, N. Dak.
Chase, C. E......Pittsburgh, Pa.
Chester, J. N....Pittsburgh, Pa.
Christie, H. L....Pittsburgh, Pa.
Christy, G. L....Pittsburgh, Pa.
Churchill, C. S....Roanoke, Va.
Claybaugh, H. W...Franklin, Pa.
Coe, C. S.....St. Augustine, Fla.
Collier, B. C......Allentown, Pa.
Collins, C. P.....Johnstown, Pa.
Connor, E. H.Leavenworth, Kans.
Constant, F. H...Princeton, N. J.
Cooley, M. E..Ann Arbor, Mich.
Covell, V. R.....Pittsburgh, Pa.
Crellin, E. W....Pittsburgh, Pa.
Crocker, H. S......Denver, Colo.
Cummings, R. A..Pittsburgh, Pa.
Cushing, W. C...Pittsburgh, Pa.

Da Lee, W. A....Pittsburgh, Pa.
Dambach, W. N..Pittsburgh, Pa.
Danzilli, A. M....Pittsburgh, Pa.
Davies, J. V......New York City
Davis, A. P...Washington, D. C.
Davis, D. E......Pittsburgh, Pa.
Davis, Meyer.....Pittsburgh, Pa.
Davison, A. S....Pittsburgh, Pa.
Davison, G. S....Pittsburgh, Pa.
de Mey, E. J. B..Pittsburgh, Pa.
Demorest, G. M..Pittsburgh, Pa.
Develin, R. G..Philadelphia, Pa.
De Vou, J. L....Pittsburgh, Pa.
Deyo, S. L. F....New York City
Dibert, H. M........Troy, N. Y.
Didier, Paul.....Pittsburgh, Pa.
Dilworth, E. C...Pittsburgh, Pa.
Doane, W. A......Meadville, Pa.
Donley, W. M....Pittsburgh, Pa.
Duis, F. B....Wheeling, W. Va.
Dunnells, C. G...Pittsburgh, Pa.
Duryea, Edwin, Jr., San Francisco, Cal.

Earl, G. G.....New Orleans, La.
Emanuel, M. C.........Erie, Pa
Emerson, C. A., Jr., Harrisburg, Pa.
Endicott, M. T., Washington, D. C.
Ericson, E. G....Pittsburgh, Pa.

Farnham, Robert, Philadelphia, Pa.
Farrington, H. P.New York City

Farris, John......Pittsburgh, Pa.
Ferguson, J. A...Pittsburgh, Pa.
Fickes, E. S.....Pittsburgh, Pa.
Fisher, E. A....Rochester, N. Y.
Fisher, S. B......Parsons, Kans.
FitzGerald, C. C..Havana, Cuba
Fleming, Thomas, Jr., Pittsburgh, Pa.
Fort, E. J.......Brooklyn, N. Y.
Foss, F. E.......New York City
Foster, E. H....New York City
Fox, C. L......Wilkinsburg, Pa.
Freeman, J. R..Providence, R. I.
Frick, Walter.....Lewisburg, Pa.
Fuller, G. W.....New York City

Gaillard, S. G..Philadelphia, Pa.
Geddes, D. Y....Zanesville, Ohio
Gibbs, E. A......Pittsburgh, Pa.
Gifford, G. E....New York City
Godfrey, Edward..Pittsburgh, Pa.
Gödfrey, Hollis..Philadelphia, Pa.
Goldmark, Henry.New York City
Goodwin, I. D...Pittsburgh, Pa.
Grafton, C. E., New Cumberland, W. Va.
Gray, S. M.....Providence, R. I.
Gregory, W. B..New Orleans, La.
Groat, B. F.....Pittsburgh, Pa.
Gudmundsson, Gisli, Pittsburgh, Pa.

Haggart, C. N...Pittsburgh, Pa.
Hall, W. M..Parkersburg, W. Va.
Hammatt, W. C., San Francisco, Cal.
Hammond, G. T..Brooklyn, N. Y.
Hansel, Charles..New York City
Haring, J. S........Crafton, Pa.
Harlan, C. H.....Pittsburgh, Pa.
Harshbarger, E. D.Pittsburgh, Pa.
Harvey, C. K....Pittsburgh, Pa.
Haskell, E. E......Ithaca, N. Y.
Haslam, E. E....Greenville, Pa.
Hatt, W. K....La Fayette, Ind.
Hatton, T. C....Milwaukee, Wis.
Haupt, Edward......Chicago, Ill.
Hawley, J. B...Fort Worth, Tex.
Hawley, W. C..Wilkinsburg, Pa.
Haydock, Charles, Philadelphia, Pa.
Hazen, Allen.....New York City
Heerlein, R. W...Pittsburgh, Pa.
Heinonen, H. J..Canonsburg, Pa.
Hench, N. M.....Pittsburgh, Pa.
Henderson, A. A..Pittsburgh, Pa.
Herschel, Clemens, New York City
Hess, E. W.......Clearfield, Pa.
Hiles, E. K......Pittsburgh, Pa.
Hopkins, N. F....Pittsburgh, Pa.
Howes, B. A......New York City
Hubbell, G. S....Pittsburgh, Pa.
Hudson, Leo......Pittsburgh, Pa.
Hughes, J. W..........Erie, Pa.
Hulse, S. C.........Bedford, Pa.
Humphreys, D. C..Lexington, Va.
Hunt, Charles Warren, New York City
Husband, C. M...Pittsburgh, Pa.

Irvin, Richard....Pittsburgh, Pa.

Jackson, S. W...Pittsburgh, Pa.
Jonah, F. G......St. Louis, Mo.
Jones, Jonathan.Philadelphia, Pa.
Jordan, J. C.....Pittsburgh, Pa.
Joyce, W. E., Montreal, Que., Canada
Judd, W. M......Pittsburgh, Pa.

Keefe, D. A.........Athens, Pa.
Keefer, C. H., Ottawa, Ont., Canada
Ketchum, M. S...Boulder, Colo.
Khuen, Richard...Pittsburgh, Pa.
Kinney, W. M......Chicago, Ill.
Knoch, J. J....Fayetteville, Ark.
Knowles, Morris..Pittsburgh, Pa.
Knox, S. B......New York City
Knutson, G. H....Jackson, Mich.

Landreth, O. H., Schenectady, N. Y.
Lantz, C. I. Morgantown, W. Va.
Lathrop, J. C....Columbus, Ohio
Laub, Hermann...Pittsburgh, Pa.
Layfield, E. N.......Chicago, Ill.
Layton, H. F.....Pittsburgh, Pa.
Lee, A. L.........Ambridge, Pa.
Leeper, J. B......Pittsburgh, Pa.
Leisen, T. A.......Detroit, Mich.
Lewis, H. M....Brooklyn, N. Y.
Lewis, N. P......New York City
Lex, W. I......Philadelphia, Pa.
Linton, Harvey......Altoona, Pa.
Lockwood, J. B. C. Portland, Ore.
Loewenstein, Jacob, New York City
Long, C. E.......Pittsburgh, Pa.
Loomis, Horace..New York City
Low, Emile.......Buffalo, N. Y.
Loweth, C. F........Chicago, Ill.
Lowinson, Oscar..New York City
Lucas, G. L......New York City
Lundie, John.....New York City
Lyon, F. W......Pittsburgh, Pa.

Machen, H. B....New York City
MacMinn, Robert. Pittsburgh, Pa.
McDonald, Hunter, Nashville, Tenn.
McGee, R. K.....Pittsburgh, Pa.
McGrew, A. B....Pittsburgh, Pa.
McHose, K. W..Wilkinsburg, Pa.
McKibben, H. S...Warren, Ohio
McLain, L. R. St. Augustine, Fla.
McNary, J. V....Harrisburg, Pa.
McNaugher, D. W., Pittsburgh, Pa.
Maitland, Alex., Jr., Kansas City, Mo.
Mangold, J. F....Grinnell, Iowa
Manning, R. G....Ambridge, Pa.
Marston, Anson......Ames, Iowa
Martin, D. H., Port Robinson, Ont., Canada
Marx, C. D., Stanford University P. O., Cal.
Mehren, E. J.....New York City
Merrill, F. S....Pittsburgh, Pa.
Metzger, F. L....Pittsburgh, Pa.
Miller, H. B....Pittsburgh, Pa.
Mitchell, S. P..Philadelphia, Pa.
Mogensen, O. E..New York City
Morse, C. M......Buffalo, N. Y.
Morse, E. K......Pittsburgh, Pa.
Mott, W. E......Pittsburgh, Pa.
Munn, H. T......Pittsburgh, Pa.

Neeld, C. M......Pittsburgh, Pa.
Neff, F. H.......Cleveland, Ohio
Neilson, G. H......Braeburn, Pa.
Norcross, P. H......Atlanta, Ga.

Ockerson, J. A....St. Louis, Mo.
O'Connor, J. A....Albany, N. Y.
Orr, D. K.......Brownsville, Pa.
Osborn, K. H...Cleveland, Ohio

Parker, D. J.....Pittsburgh, Pa.
Pegram, G. H....New York City
Pendergrass, R. A., Pittsburgh, Pa.
Perkins, W. W. C. Conneaut, Ohio
Phelps, E. B..Washington, D. C.
Porter, H. T.....Greenville, Pa.
Potter, Alexander, New York City
Prichard, H. S...Pittsburgh, Pa.

Querbach, Earl....Ambridge, Pa.
Quick, R. S......Pittsburgh, Pa.
Quimby, H. H..Philadelphia, Pa.
Quincy, Edmund..New York City

Rankin, H. H....Pittsburgh, Pa.
Raymer, A. R....Pittsburgh, Pa.
Reppert, C. M....Pittsburgh, Pa.
Reynders, J. V. W. New York City
Rice, J. M. T....Pittsburgh, Pa.
Ridgway, Robert..New York City

Riegler, L. J.....Pittsburgh, Pa.
Rights, L. D.....New York City
Rollins, J. W., Jr..Boston, Mass.
Royal, J. N......Pittsburgh, Pa.
Rue, M. A.......New York City
Rust, H. B.......Pittsburgh, Pa.

Safford, H. R., Montreal, Que., Canada
Sax, P. M......Philadelphia, Pa.
Scaife, W. L.....Pittsburgh, Pa.
Schade, C. G.....Pittsburgh, Pa.
Scharff, M. R....Pittsburgh, Pa.
Schein, Nathan...Pittsburgh, Pa.
Schlumpf, O. L...Sewickley, Pa.
Scott, Guy.....Fort Wayne, Ind.
Seaman, H. B....New York City
Shoemaker, L. H..Pittsburgh, Pa.
Sickman, A. F...Holyoke, Mass.
Simpson, G. H...Pittsburgh, Pa.
Skinner, J. F..Rochester, N. Y.
Slater, W. A........Urbana, Ill.
Smith, J. R.......Braddock, Pa.
Smith, J. Waldo..New York City
Snow, F. H.....Harrisburg, Pa.
Sortore, A. E....Pittsburgh, Pa.
Sprague, E. M...Cleveland, Ohio
Sprague, N. S....Pittsburgh, Pa.
Stevenson, J. D..Pittsburgh, Pa.
Strachan, Joseph.Brooklyn, N. Y.
Straub, T. A....Pittsburgh, Pa.
Summers, R. E. J., Wilkinsburg, Pa.
Swain, G. F.......Boston, Mass.
Swensson, Emil...Pittsburgh, Pa.
Swensson, O. J......Troy, N. Y.

Talbot, A. N........Urbana, Ill.
Talbot, K. H....Pittsburgh, Pa.
Tarr, C. W.........Oakdale, Pa.
Taylor, B. H....Pittsburgh, Pa.
Taylor, E. B.....Pittsburgh, Pa.
Taylor, G. L.....Pittsburgh, Pa.
Taylor, S. A....Pittsburgh, Pa.
Thayer, H. R....Pittsburgh, Pa.
Thorley, I. O.......Denver, Colo.
Tinker, G. H....Cleveland, Ohio
Tinkham, S. E.....Boston, Mass.
Titsworth, R. B...Edgewood, Pa.
Todd, C. L.......Pittsburgh, Pa.
Tolman, E. M.Charleston, W. Va.
Townsend, C. McD., St. Louis, Mo.
Trautwine, J. C., Jr., Philadelphia, Pa.
Triest, W. G....New York City
Tuttle, A. S.....New York City

Underhill, G. G....Albany, N. Y.

Van Ornum, J. L..St. Louis, Mo.

Waddell, J. A. L.Kansas City, Mo.
Walker, J. W..Port Kennedy, Pa.
Watters, G. L., South Bethlehem, Pa.
Weiss, H. O.....New York City
Weller, F. R..Washington, D. C.
White, T. S....Beaver Falls, Pa.
Whitney, J. T..Steubenville, Ohio
Wilcox, C. L.....Pittsburgh, Pa.
Wilcox, Frank....Pittsburgh, Pa.
Wilkerson, T. J..Pittsburgh, Pa.
Wilkins, W. G....Pittsburgh, Pa.
Williams, G. S..Ann Arbor, Mich.
Williams, Marshall, Pittsburgh, Pa.
Williams, S. D., Jr., St. Thomas, Ont., Canada
Williamson, C. S...Chicago, Ill.
Willoughby, J. E., Wilmington, N. C.
Wilson, H. M....Pittsburgh, Pa.
Wolfel, P. L.....Pittsburgh, Pa.
Woodworth, R. B.Pittsburgh, Pa.
Wooldridge, C. L.Pittsburgh, Pa.
Wuest, Charles, Jr., Cincinnati, Ohio

Yappen, Adolph.....Chicago, Ill.

Zearley, E. L.....Uniontown, Pa.

SOCIETY ITEMS OF INTEREST

CHANGE OF SOCIETY HEADQUARTERS

Canvass of Ballots on Movement of Society Headquarters

Report of the Tellers

Board of Direction
American Society of Civil Engineers:

The Tellers appointed to canvass the ballots on the Proposed Change of Society Headquarters report as follows:

Total number of ballots received		3 027
Ballots from members in arrears of dues	42	
" without signatures	12	
" stamped, not signed	10	
Number of ballots not canvassed		64
Number of ballots canvassed		2 963

			Majority
(1) Shall the American Society of Civil Engineers accept one of the offers made in behalf of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, through the United Engineering Society?	Yes	2 500	
	No	390	2 110 In favor.
(2) If the result of this ballot is in the affirmative:			
(*a*) Do you favor Plan "A" as outlined?	Yes	1 096	
	No	248	848 In favor.
(*b*) Do you favor Plan "B" as outlined?	Yes	194	
	No	695	501 Against.
(*c*) Do you favor leaving the question of the plan to be accepted in the hands of the Board of Direction?	Yes	1 795	
	No	524	1 271 In favor.

Arthur S. Tuttle,
Lincoln Bush,
J. V. Davies,
Clemens Herschel,
Chas. Warren Hunt,
Tellers.

June 15th, 1916.

Change of Society Headquarters (*Continued*).

Resolutions Adopted by the Board of Direction of the American Society of Civil Engineers, June 23d, 1916

Whereas, the following resolution was passed by the Trustees of United Engineering Society on June 24th, 1915, to wit:

> "*Resolved,* That out of its desire to welcome the American "Society of Civil Engineers into the fraternity of the Founder "Societies and with a sense of the increased dignity and use-"fulness to the engineering profession which this adherence of "the American Society of Civil Engineers would contribute, the "United Engineering Society hereby desires to express the senti-"ment in favor of coalition which has been growing, and to invite "the American Society of Civil Engineers to consider entering "the United Engineering Society as an additional Founder "Society; and the President is authorized to appoint a Committee "to confer with any corresponding Committee of the American "Society of Civil Engineers in the formation of a tentative plan "which if this invitation is accepted can be referred on the part "of the United Engineering Society to the governing bodies of "the Founder Societies for their action."

and

Whereas, such resolution has been approved by the governing bodies of the American Institute of Mining Engineers, the American Society of Mechanical Engineers and the American Institute of Electrical Engineers, and was likewise considered and approved by the Board of Direction of this Society, and

Whereas, conferences have been held between a Committee representing the United Engineering Society, and a Committee representing this Society, and offers have been made in letters dated July 6th, 1915, August 23d, 1915, and October 28th, 1915, by the Committee of the United Engineering Society to the Committee representing this Society, and

Whereas, by special ballot, canvassed June 15th, 1916, 2 500 of the Corporate Members of this Society voted in favor of the acceptance of the invitation of the United Engineering Society, and only 390 Corporate Members voted against such acceptance, and

Whereas, on that ballot the sentiment of a majority of those voting on each of the plans submitted was expressed in favor of the plan which provides for the addition of three stories to the present building of the United Engineering Society, and against the plan which does not provide for such additional stories, be it

Resolved, That this Board, acting in behalf of the American Society of Civil Engineers, accepts the invitation of the United Engineering Society made, in behalf of the American Institute of Mining Engineers, the American Society of Mechanical Engineers, and the American Institute of Electrical Engineers, to become one of the Founder Societies, in accordance with the terms and conditions contained in the before mentioned letter, dated July 6th, 1915, as

Change of Society Headquarters (*Continued*).

modified by the before mentioned letter, dated August 23d, 1915, which provide for the construction of three additional stories to the present building of the United Engineering Society, at an estimated cost of $225 000. It is understood, in accordance with the terms of said letters, that the cost to this Society in any event is not to exceed $250 000.

Resolved, That Clemens Herschel, Chas. Warren Hunt, and J. V. Davies be and are hereby authorized for, and in behalf of, this Society, to execute any agreements or other instruments that may be appropriate for carrying into effect, in accordance with the above, the plan whereby this Society shall enter the United Engineering Society as an additional Founder Society, this Society assuming therein an obligation to defray the expenses of such building operations, at a cost not to exceed $250 000.

Resolved, That the whole question of financing the movement of Headquarters of the Society be referred to the Finance Committee for report, this to include action to be taken with regard to the sale of the Fifty-seventh Street property.

Clemens Herschel, Chas. Warren Hunt, and J. V. Davies, were appointed to represent the Society as members of the United Engineering Society whenever the American Society of Civil Engineers becomes legally one of the Founder Societies.

MEMORANDUM AGREEMENT

BETWEEN UNITED ENGINEERING SOCIETY

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

AMERICAN INSTITUTE OF MINING ENGINEERS

AND

THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Memorandum of Agreement entered into this twenty-fifth day of July, 1916, between UNITED ENGINEERING SOCIETY, party of the first part, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, party of the second part, THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, party of the third part, AMERICAN INSTITUTE OF MINING ENGINEERS, party of the fourth part, and THE AMERICAN SOCIETY OF CIVIL ENGINEERS, party of the fifth part.

The party of the first part being incorporated by an Act of the Legislature of the State of New York which became a law May 11th, 1904, and being the owner of premises consisting of land and its Building erected thereon known as the Engineering Societies Build-

Change of Society Headquarters (*Continued*).

ing, and located on West 39th Street, in the Borough of Manhattan, in the City of New York, and the parties of the second, third, and fourth parts hereto, being Founder Societies of the party of the first part, and an invitation having been extended by the party of the first part to the party of the fifth part to enter into the Fraternity of said Founder Societies by becoming a Founder Society of the party of the first part, such invitation meeting with the hearty approval of the parties of the second, third and fourth parts hereto, and the same having been accepted by the party of the fifth part hereto.

Now, for the purpose of consummating the plan for the entry of the party of the fifth part as such Founder Society which has been agreed to between the parties hereto, this Agreement *Witnesseth:*

First: The parties hereto and each of them do hereby agree that the party of the fifth part shall become a Founder Society of the party of the first part with like rights and relations in and with the party of the first part and with each of the other parties hereto as those now possessed and existing by and between the parties of the first, second, third and fourth parts.

Second: To that end the parties of the second, third, fourth and fifth part hereto and each of them do hereby request the party of the first part to enlarge its building above mentioned by adding thereto three additional stories as provided for by plans heretofore filed in the Building Department by Henry G. Morse, Architect, with such modifications as may be requisite or appropriate to meet legal requirements or as may be approved of by the Architect and the building Committee of the party of the first part and the party of the first part agrees so to do. The cost of making such enlargement not exceeding, however, the sum of $250,000 will be paid by the party of the fifth part as its contribution as a Founder Society, and in lieu of the contribution which said party of the fifth part would have made under the Founder's Agreement between the aforementioned Founder Societies and the party of the first part, if the party of the fifth part had been originally a Founder Society of the party of the first part. The amount so contributed by the party of the fifth part shall be paid and advanced under and upon the terms of Treasurer's receipts of the party of the first part which shall be issued to the party of the fifth part at par for the amounts so contributed or advanced from time to time in the same form as Treasurer's receipts provided for in said Founder's Agreement, and the rights of the party of the fifth part growing out of, or respecting such contribution shall be identical with the rights of the existing Founder Societies respectively growing out of the payments or contributions made by them evidenced by

Change of Society Headquarters (*Continued*).

Treasurer's receipts provided for in said Founder's Agreement. In arriving at cost of enlargement under this contract interest at the rate of four and one-half per cent. ($4\frac{1}{2}\%$) on payments made prior to the completion of such enlargement shall be deemed to be part of such cost.

Third: The party of the first part agrees that any excess over the sum of $250,000 in the cost of making the above mentioned enlargement to its building will be borne and paid by the party of the first part.

Fourth: Upon the party of the fifth part becoming a Founder Society its Library shall be added to the joint Library of the parties of the first, second, third and fourth parts to be controlled and administered as one joint Library by the Library Board of the United Engineering Society in accordance with the By-Laws of such Society, and each of the parties hereto agrees that upon the party of the fifth part becoming a Founder Society, it will enter into a Library Agreement with respect to such joint Library as increased by the Library of the party of the fifth part, which said agreement shall, with the omission of paragraphs "9th" and "10th" thereof, and the addition of the party of the fifth part as a party thereto, be in like form as the existing Library Agreement between the existing Founder Societies and the party of the first part.

Fifth: The parties hereto severally agree that upon the party of the fifth part becoming a Founder Society they will enter into a new Founder's Agreement which shall supplant and be a substitute for the existing Founder's Agreement, and which said new Agreement shall read as follows, to wit:

"MEMORANDUM OF FOUNDER'S AGREEMENT entered into this "day of 191 , between UNITED ENGINEERING SOCIETY, "party of the first part, AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS, "party of the second part, THE AMERICAN SOCIETY OF MECHANICAL "ENGINEERS, party of the third part, AMERICAN INSTITUTE OF MINING "ENGINEERS, party of the fourth part, and THE AMERICAN SOCIETY OF "CIVIL ENGINEERS, party of the fifth part.

"The party of the first part being incorporated by an Act of the "Legislature of the State of New York which became a law May 11th, "1904, and being the owner of land and a building erected thereon "known as the Engineering Societies Building, located on West 39th "Street, in the Borough of Manhattan, in the City of New York, and "the parties of the second, third and fourth parts having been hereto-"fore Founder Societies of the party of the first part, and having "together with said party of the first part on or about January 26th, "1905, executed an agreement known as the Founder's Agreement as "provided for in the By-Laws of the party of the first part, and the

Change of Society Headquarters (***Continued***).

"party of the fifth part having become an additional Founder Society "of the party of the first part, with like rights and relations in and with "the party of the first part, and with the parties of the second, third "and fourth parts, as those heretofore possessed and existing by and "between the parties of the first, second, third and fourth parts, and "the parties of the second, third and fourth parts having heretofore "each made certain payments or advances by way of contribution to "the United Engineering Society under and upon the terms of Treas-"urer's receipts, provided for in said Founder's Agreement, and the "party of the fifth part hereto having heretofore agreed, as its con-"tribution to said United Engineering Society, and in lieu of the "contribution which it would have made under said original Founder's "Agreement if it had been originally a Founder Society, to pay the "cost of the enlargement of the said building, not exceeding however, "the sum of $250,000 as is more fully provided for by agreement "between the parties hereto dated the day of 191 , such "contribution by the party of the fifth part to be made under and "upon the terms of the Treasurer's receipts of the party of the first "part hereinafter set forth, and

"*Whereas,* for the aforementioned contributions heretofore made "by each of the parties of the second, third and fourth parts, such "Treasurer's receipts have been issued, and

"*Whereas,* the parties of the second, third, fourth and fifth parts "hereto are desirous of enjoying the privileges of Founder Societies "of the said party of the first part as provided for in the By-Laws of "the said United Engineering Society, now these presents *Witnesseth:*

"The parties of the second, third, fourth and fifth parts do severally, "each for themselves and not for each other, promise and agree to "and with each other and with the party of the first part, to perma-"nently maintain their principal offices in the building of the party "of the first part, subject to the provisions of the By-Laws of the "United Engineering Society as they now exist or may hereafter be "amended, such agreements of the parties of the second, third and "fourth parts being effective now, and such agreement of the party "of the fifth part to become effective from, and beginning with the "time of the completion of the enlargement above mentioned. The "amounts heretofore contributed to the party of the first part by the "parties of the second, third and fourth parts having been paid and "advanced under and upon the terms of Treasurer's receipts of the "party of the first part issued at par for the amounts so paid or ad-"vanced from time to time in the following form, it is agreed that "the contribution of the party of the fifth part for, or towards the cost "of making the enlargement of the building hereinabove mentioned, "not exceeding the sum of $250,000 shall likewise be paid and ad-"vanced under and upon the terms of such Treasurer's receipts of the "party of the first part, which shall be issued at par for the amounts "so paid or advanced from time to time, such Treasurer's receipts to "be in the following form, to wit:

Change of Society Headquarters (*Continued*).

" 'Treasurer's Receipts.'

" '*This Certifies that United Engineering Society* (herein called " 'the payee) has received from American of " 'Engineers (herein called the payor) the sum of dollars " '($) to be used and invested by the payee in carrying out " 'its corporate purposes, said amount being so paid as part considera- " 'tion for the admission of the payor as a Founder Society of the " 'payee, under and subject to the by-laws of the payee.

" '*It is Agreed* by the payor that interest on the amount of this " 'receipt is and will be deemed discharged by privileges accorded to " 'the payor as a Founder Society as provided in the by-laws of the " 'payee, and that no right to recover any of the principal of such " 'amount or interest thereon, shall exist so long as the payee shall be in " 'existence and perform its corporate functions. Neither this receipt " 'nor the claim for the amount evidenced thereby is transferable and " 'any assignment or encumbrance of said receipt or claim, shall make " 'the same void. Neither this receipt nor said claim shall be redeemable " 'or payable excepting out of such portion of the reserve fund of the " 'payee as may be appropriated therefor by a vote of the majority of " 'the representatives of each of the Founder Societies on the Board " 'of Trustees of the payee, as such Board shall then be constituted, " 'it being understood that any such appropriation, if made, shall be " 'applied pro rata upon such of the claims represented by treasurer's " 'receipts issued to and then held by such of the Founder Societies " 'as shall then be represented in the Board of Trustees of the payee. " 'This receipt and the claim evidenced thereby, shall not be subject " 'to any indebtedness of the payor to the payee and shall become void " 'as an evidence of indebtedness or obligation to said payor in case " 'said payor shall for any cause cease to have representation upon the " 'Board of Trustees of the payee.

" 'United Engineering Society.
" ' . . . . *Treasurer.*
" ' . . . . *President.*
" 'Dated, New York . . . . 19 .'

"*And each of the Parties of* the second, third, fourth and fifth "parts hereto does further covenant and agree severally, and each "only for itself, to and with each other, and to and with the party of "the first part, that it will abide by and comply with the by-laws of "the party of the first part and will pay when due all assessments "levied against it, in accordance with the by-laws of the party of the "first part. The party of the first part, in consideration of this agree- "ment, has adopted its by-laws, and has admitted or will admit the "parties of the second, third, fourth and fifth parts hereto, as Founder "Societies, in accordance with the provisions thereof, and has acquired "property and assumed obligations for the purpose, among other "things, of enabling it to accord privileges in its building to the parties "of the second, third and fourth and fifth parts, and this instrument "is executed by the parties of the second, third, fourth and fifth parts

Change of Society Headquarters (*Continued*).

"hereto in consideration thereof, and to induce said party of the first "part to take such action. And each of the several parties hereto has "assumed the obligations herein contained in consideration of the "agreements and obligations of each of the other parties hereto.

"This agreement is entered into in lieu of, and as a substitute for "the Founder's Agreement heretofore entered into between the first "four parties hereto, it being agreed however, that the Treasurer's "receipts heretofore issued pursuant to the original Founder's Agree-"ment shall remain operative and of the same order of validity and "priority as Treasurer's receipts to be issued hereunder to the party "of the fifth part,

"In Witness Whereof, the several parties hereto have caused these "presents to be executed by their respective officers and their cor-"porate seals to be hereunto affixed."

Sixth: The parties hereto severally agree that they will, with all convenient speed, cause the By-Laws of the party of the first part to be amended in such respects as may be necessary to carry into effect the purposes of this Agreement, and that they will do and cause to be done, such acts and execute such instruments as may be necessary or reasonably appropriate to carry into effect such purposes.

Seventh: Pending the completion of the enlargement of said building and in anticipation of the formal execution of this instrument by the parties of the second, third and fourth parts hereto, the parties of the first and fifth parts may, upon the execution of this agreement by them, proceed with the aforementioned enlargement of said building and any sums paid or advanced in that behalf by the party of the fifth part shall be deemed to be paid and advanced towards such enlargement under and pursuant to the terms and provisions of this agreement. With respect to any payments required to be made from time to time for the cost of the above mentioned enlargement, the party of the fifth part shall have thirty days from notice to it by the Building Committee that such amount will be required, within which to pay the same.

Eighth: No assessment for space other than in connection with the Library shall be made against the party of the fifth part until the Building Committee shall certify that the above mentioned enlargement is ready for occupancy.

Ninth: Annexed hereto, marked "A" is a copy of the Charter and By-Laws of the party of the first part, and annexed hereto, marked "B" and "C" are copies of notices of proposed amendments to the By-Laws of the party of the first part, and annexed hereto, marked "D" is a copy of the Library Agreement hereinabove referred to, and the first four parties hereto agree that they will cause the adoption of said amendments and of each of them as soon as practicable.

In Witness Whereof, this Agreement has been executed by the representatives of the respective parties hereto thereunto duly author-

Change of Society Headquarters (*Continued*).

ized and the seals of the respective parties hereto have been hereunto duly affixed the day and year first above mentioned.

United Engineering Society
By Charles F. Rand, *President,*
Jos. Struthers, *Treasurer.*

American Institute of Electrical Engineers
By H. W. Buck, *President,*
F. L. Hutchinson, *Secretary.*

The American Society of Mechanical Engineers
By D. S. Jacobus, *President,*
Calvin W. Rice, *Secretary.*

American Institute of Mining Engineers
By L. D. Ricketts, *President,*
Bradley Stoughton, *Secretary.*

The American Society of Civil Engineers
By Clemens Herschel, *President,*
Chas. Warren Hunt, *Secretary,*
J. Vipond Davies, *Director.*

Exhibit A.

Attached Separately in Bound Form.*

Exhibit B.

Proposed Amendments to the By-Laws of the United Engineering Society.

(1) Amend Section 6 by adding thereto the following:

"The entry of an additional Founder Society shall be evi- "denced by a similar certificate modified to conform to the facts, "and executed by the Board of Trustees or a majority thereof."

and striking out "as hereinafter provided."

(2) Amend Section 7 by substituting a comma for the period at the end thereof, and adding "Civil" in quotations and then a period.

(3) Amend Section 13 by making it read as follows:

"The Board of Trustees shall consist of twelve members, three "of them representing the American Institute of Electrical Engi- "neers, three of them representing the American Society of "Mechanical Engineers, three of them representing the American "Institute of Mining Engineers, and three of them representing "the American Society of Civil Engineers."

(4) Amend Section 14 by inserting at the beginning thereof the following:

"Each of the Founder Societies shall, at the outset, elect, ap- "point or designate its representatives upon the Board of Trustees

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* Charter and By-Laws of the United Engineering Society.

Change of Society Headquarters (*Continued*).

"by making provision for the expiration of the terms of office of "said representatives so that the term of one shall expire on the "adjournment of the next ensuing annual meeting; that of another "one (1) year thereafter, and that of another two (2) years "thereafter,"

and by adding after the words "the American Institute of Mining Engineers," the words "and the American Society of Civil Engineers," and striking out the word "and" before the words "the American Institute of Mining of Engineers."

(5) Amend Section 22 by substituting "twelve" for "nine," and "nine" for "seven."

(6) Amend Section 40 by substituting "seven" for "five."

(7) Amend Section 76 by substituting "nine" for "seven".

(8) Amend Section 77 by substituting "nine" for "seven."

(9) Amend Section 81 by substituting "nine" for "seven."

(10) Amend Section 107 by striking out the words "three" in two places where they occur.

(11) Amend Section 108 by substituting "nine members" for "seven members."

(12) Amend Section 124 by making it read as follows:

"The Engineering Foundation Board shall be constituted "as follows:

"From United Engineering Society while remaining members "of its Board of Trustees or until their successors are elected, "four members, consisting of one representative of each Founder "Society.

"From each Founder Society, upon the nomination of its "governing body, one member not a member of the Board of "Trustees of United Engineering Society.

"Two members at large.

"The President of United Engineering Society ex-officio."

(13) Amend Section 135 by adding after the words "Mining Engineers," the words "and The American Society of Civil Engineers."

(14) Amend Section 142 by substituting "nine" for "seven."

EXHIBIT C.

PROPOSED AMENDMENT TO THE BY-LAWS OF THE UNITED ENGINEERING SOCIETY

Amend Section 74 by striking out the following, viz.:

"In making such assessment the Board shall be under no ob-"ligation to apportion the amount of the Budget equally between "the societies, or equally between any two or more of them, but "the Board shall, in making such assessment, take into considera-"tion the expenses of the society through the occupation by the "various Founder and Associate Societies of the respective por-"tions of the building occupied by each, and the facilities afforded "to the respective Founder and Associate Societies"

Change of Society Headquarters (*Continued*).

and inserting in lieu thereof, the following:

"That portion of the budget in each year to be assessed against "the Founder Societies other than the amount which they may "be assessed for for allotment of space occupied by them shall be "assessed against them in equal amounts."

EXHIBIT D—LIBRARY AGREEMENT

EXECUTED BY UNITED ENGINEERING SOCIETY AND THE FOUNDER SOCIETIES IN FEBRUARY, 1915

AGREEMENT

THE AMERICAN INSTITUTE OF MINING ENGINEERS

THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

THE AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

(known as the "Founder Societies")

and the

UNITED ENGINEERING SOCIETY

in consideration of one dollar by each to the other in hand paid, the receipt whereof is hereby acknowledged, and of the mutual agreements herein contained, hereby agree, each with the other, that—

1st. The present Library of each of the said societies shall remain the property of that Society, each book or other article of each Library shall bear the bookplate of its owner.

2d. The four libraries of the said societies shall be controlled and administered as one Joint Library by the Library Board of the United Engineering Society, in accordance with the By-Laws of that Society.

3d. The future current purchase of books, periodicals and other literature for addition to the Joint Library, shall, under the direction of and with the approval of the Library Board, be made and paid for by the United Engineering Society; and each such purchase shall be the property of and bear the bookplate of the United Engineering Society; except that future purchases by the United Engineering Society of additional numbers to any serial publication now in the Library, shall carry the same bookplate as the earlier numbers and the entire publication shall continue to be the property of the Society represented by the bookplate.

4th. The cost of binding, the salaries of the Librarian and of all assistants, all supplies and other current expenses for the Library, shall, when approved by the Library Board, be paid by the United Engineering Society.

5th. The United Engineering Society, shall, as far as in its judgment its financial condition will permit, pay in each year the current expenses for books and all other costs of the administration of the Joint Library for the same year; and it shall have authority, now conferred by this agreement, to make equal assessments on each of the Founder Societies, to provide such additional funds as may be required, for the payment of said current expenses of the Library.

Change of Society Headquarters (*Continued*).

6th. The Library Board shall not incur or authorize bills of expense for books, or for the administration of the Library or for any other purpose in excess of the allowance for the Library in the budget of the United Engineering Society for the current year.

7th. The accounts of all income and expenditure for the Library shall be kept in the books of the United Engineering Society and such accounts shall be open to the inspection of any officer of any Founder Society.

8th. This agreement shall not in any way preclude any Founder Society from acquiring by purchase from its own funds, or by gift or exchange, any books, periodicals or other articles for its own library, and placing them in the Joint Library as its own property under its own bookplate.

The care and binding of such books, periodicals or other articles so acquired and placed, shall be at the expense of the United Engineering Society so long as they remain in the Joint Library.

9th. The agreement shall not become binding until it has been approved by resolution of the governing body of each of the four societies, parties hereto, and attested by the signatures of the President and Secretary of each.

10th. The agreement when formally approved and signed shall take effect as of January 1, 1915.

Agreement Carried Out

At its meeting of August 10th, 1916, the United Engineering Society carried out the above agreement by making the necessary changes in its By-laws, and the American Society of Civil Engineers thus became one of the four Founder Societies, the representatives of the Society in the United Engineering Society being Clemens Herschel, Chas. Warren Hunt, and J. Vipond Davies.

Building Committee

On July 6th, 1916, the President of the United Engineering Society appointed the following Building Committee, consisting of a representative of each of the four constituent Societies: H. H. Barnes, Jr., Chairman, H. G. Stott, Chas. Warren Hunt, and Charles F. Rand.

The Committee has held a number of meetings, and has awarded a contract for preliminary structural work, and the work was started by the Contractor, August 1st, 1916.

Joint Conference Committee
of the
Four National Engineering Societies

This Committee consists of three representatives from each of the following:

American Society of Civil Engineers,
American Institute of Mining Engineers,
American Society of Mechanical Engineers,
American Institute of Electrical Engineers.

It has been acting under a Resolution adopted by each of the four Societies which gives

> "to the Joint Conference Committee of Engineering Societies authority to take action on all general or public matters relating to the welfare of the Profession, and in connection with which joint action seems desirable; on the condition that the Joint Conference Committee records in its minutes any action taken and reports such action for approval at the next subsequent meeting of the governing bodies of each of the constituent societies."

At its meeting of June 16th, 1916, the following Resolution was adopted:

> "The Joint Conference Committee of Engineering Societies believes that the development of the country's undeveloped water power will increase national prosperity; that private enterprise should be encouraged and stimulated to expedite such development; that unnecessary legal burdens should be removed and existing doubts as to the safety of investment eliminated. It commends to the support of engineers all efforts made to secure the fullest publicity as to the underlying facts regarding this subject."

Calvert Townley, Chairman, and Chas. Warren Hunt, Secretary of the Committee, were authorized to give this Resolution publicity.

In a letter dated June 28th, 1916, the Secretary called the attention of the President of the United States to this action and to the fact that the Committee acts in behalf of about 30 000 Engineers.

Arizona Meeting of the
American Institute of Mining Engineers

In connection with the Arizona Meeting of the American Institute of Mining Engineers, September 18th to 25th, 1916, a Special Train Tour of the Arizona Mining Districts and the Grand Canyon has been arranged.

The special train will leave the Grand Central Terminal, New York, at 5.30 P. M., on Thursday, September 14th, 1916, and, going by way of Chicago, Kansas City, Topeka, El Paso, Santa Rita, Douglas, and Bisbee, will arrive at Globe, Ariz., at 9 A. M. on Thursday, September 21st. Mines, mills, and reduction works at Santa Rita, Hurley, Douglas, Bisbee, and Globe will be visited, and technical sessions will be held at several places *en route*. Two days will be spent at Globe, and visits will be made to the Roosevelt Dam, the Grand Canyon, the Cliff Dwellings, etc. Returning, the train will go by way of Phœnix, Albuquerque, La Junta, Kansas City, and Chicago, and will arrive in New York on Thursday, September 28th, at 9.40 A. M.

Members of the American Society of Civil Engineers will be welcomed on this trip, and may join the party at any point *en route*. Any member of this Society who is interested may obtain full particulars by addressing the Secretary of the Institute, Mr. Bradley Stoughton, 29 West 39th Street, New York City.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

September 6th, 1916. 8.30 P. M.—A regular business meeting will be held, and a paper by J. C. Allison, Assoc. M. Am. Soc. C. E., entitled "Control of the Colorado River as Related to the Protection of Imperial Valley", will be presented for discussion.

This paper was printed in *Proceedings* for May, 1916.

September 20th, 1916.—8.30 P. M.—At this meeting, a paper by Israel V. Werbin, Assoc. M. Am. Soc. C. E., entitled "Tunnel Work on Sections 8, 9, 10, and 11, Broadway-Lexington Avenue Subway, New York City", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

October 4th, 1916.—8.30 P. M.—This will be a regular business meeting. A paper by H. de B. Parsons, M. Am. Soc. C. E., entitled "Underpinning Trinity Vestry Building for Subway Construction", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this

can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings*.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

President, H. L. Haehl; Secretary, E. T. Thurston, 57 Post Street, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meetings)

April 18th, 1916.—The meeting was called to order at the Palace Hotel; President H. L. Haehl in the chair; E. T. Thurston, Secretary; and present, also, 78 members and guests.

The reports of the Committees appointed by the Entertainment Committee, namely, the Committee on Compensation of Engineers (H. C. Vensano), the Committee on General Conditions for Specifications (F. H. Tibbetts), and the Committee on Education of Engineers (M. H. Brinkley), were presented.

Messrs. F. H. Fowler, G. A. Elliott, and Thomas H. Means were appointed as the Entertainment Committee for the June meeting.

A communication from Treasurer P. E. Harroun was read relative to consolidating the offices of Secretary and Treasurer and suggesting that the three latest living Past-Presidents constitute the Board of Directors. After some discussion and amendment reducing the Board of Directors to five, Article IV, Sections 1 and 2, of the Constitution, was changed to read as follows, the change to take effect at the end of the current year:

"Article IV.

"Officers

"Section 1. The officers of this Association shall be a president, two vice-presidents, and a secretary-treasurer, who, with the latest living past-president, shall constitute a board of directors in which the government of the Association shall be vested.

"Section 2. The terms of the office of the president of the Association shall be one year, of the vice-presidents and secretary-treasurer, two years. The term of each officer shall begin at the close of the annual meeting at which such officer is elected, and shall continue for the period above named, or until a successor is duly elected."

Relative to the question of the proposed merger of the Society with the United Engineering Society, the Secretary read communications on the subject from various sources. After considerable discussion, a motion that a vote be taken on "Proposition A" was laid on the table.

On motion, duly seconded, consideration of the suggestions for the extension of the influence and work of the Association, as embodied in the Inaugural Address of President Haehl, was laid over until the June meeting.

On motion, duly seconded, the President was instructed to appoint a committee of three to draw up and present to the proper authorities and publish in the newspapers, a resolution expressing the confidence of the members of the Association in Mr. L. H. Nishkian, who through political influence had been removed from his position as Engineer in the Department of Buildings of San Francisco. President Haehl subsequently appointed Messrs. H. J. Brunnier, J. D. Galloway, and M. C. Couchot as such Committee.

At the request of the Chairman, Mr. Galloway addressed the meeting briefly on preparedness from an engineer's standpoint, and sug-

gested the appointment of a committee to consider the question. On motion, duly seconded, the Chairman was instructed to appoint a committee of three to consider the subject, and Messrs. Galloway, Allan, and Rhodin were named.

A paper by Mr. M. M. O'Shaughnessy entitled "Some Observations, Professional and Otherwise, Made in Connection with a Recent Journey East", was presented by the author.

Adjourned.

June 20th, 1916.—The meeting was called to order at the Palace Hotel; President H. L. Haehl in the chair; E. T. Thurston, Secretary; and present, also, 40 members and guests.

The Entertainment Committee showed a series of moving pictures illustrating the laying of the submarine cables from Oakland to San Francisco for the Great Western Power Company and the Pacific Gas and Electric Company, respectively, and of the construction work on the hydraulic-fill dam at Calaveras Creek for the Spring Valley Water Company.

The Secretary read the report of the Preliminary Committee on Military Affairs, in which it was stated that a joint mass meeting of local members of the National Engineering Societies was held on May 2d, 1916, at which the attendance was about 300; papers were read by Capt. Parks, Corps of Engineers, U. S. A., Capt. Murphy, Coast Artillery, U. S. A., and by Mr. Allen Babcock, of the California Section of the Naval Consulting Board, and a resolution was adopted authorizing the appointment of a Permanent Joint Committee on Military Affairs consisting of three members from each of the Local Societies. President Haehl appointed Messrs. Galloway, Campbell, and Means to represent the Association on such Committee.

On motion, duly seconded, the original Committee was discharged with a vote of thanks.

A partial report of the Permanent Committee on Military Affairs was presented by the Secretary, announcing its organization, and that a circular describing its possible activities, etc., had been forwarded to Society members in California and Nevada. A resolution which accompanied this report, relative to the formation of a National Joint Committee on Military Affairs, was adopted unanimously by the Association.

The Secretary read letters from the Baltimore Association relative to its contribution to the State Board of Directors on Industrial Preparedness of Maryland, and from the Committee of Secretaries of the San Francisco Associations outlining a scheme of co-operation between the respective local societies in regard to meetings, etc.

A summary of the suggestions relative to extending the influence and work of the Association, as embodied in the Inaugural Address of President Haehl, was presented by the Secretary, and after discussion by Messrs. Snyder, Harroun, Dockweiler, and Griffin, the President was instructed to appoint a committee of three to consider the suggestions at the August meeting. The President subsequently appointed Messrs. Harroun, Huber, and Griffin as such Committee.

Mr. B. P. Legaré addressed the meeting relative to the Preparedness Parade to be held on July 22d, 1916, and the efforts being made to secure a proper representation of Engineers for that occasion. After some discussion, on motion, duly seconded, the official endorsement of the Association was given the parade, and the Board of Directors was authorized to co-operate in making up any deficit accruing in carrying out the project.

The President appointed Messrs. H. H. Hall, P. E. Brown, and E. L. Cope as the Entertainment Committee for the August meeting.

A paper by Mr. H. A. Whitney entitled "The Organization of Municipal Water Departments", was presented by the author, and discussed by Messrs. Schussler, Dockweiler, and others.

Adjourned.

Colorado Association, Organized 1908.

President, John E. Field; Secretary-Treasurer, L. R. Hinman, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays, at 12.30 P. M., at Clarke's Restaurant, 1632 Champa Street.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

President, Paul H. Norcross; Secretary-Treasurer, Thomas P. Branch, Georgia School of Technology, Atlanta, Ga.

The Association holds its meetings at the University Club, Atlanta, Ga. Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

Baltimore Association, Organized 1914.

President, H. D. Bush; Secretary-Treasurer, Charles J. Tilden, The Johns Hopkins University, Baltimore, Md.

(Abstract of Minutes of Meeting)

May 3d, 1916.—The Annual Meeting was called to order at 8.35 P. M., in the Donovan Room of The Johns Hopkins University; President Thomas D. Pitts in the chair; C. J. Tilden, Secretary; and present, also, 14 members and 1 guest.

The minutes of the meeting of May 5th, 1915, were read and approved.

Messrs. Janney, Mackall, Hartman, and Requardt were appointed a Nominating Committee to prepare a list of officers for the ensuing year.

The Secretary read various communications received by the Association relative to the proposed change of Society Headquarters. The subject was discussed, but no formal action was taken.

The reports of the Secretary-Treasurer for the year ending May 1st, 1916, were presented.

On motion, duly seconded, the President was instructed to appoint a committee to revise the Constitution of the Association, the proposed revision to be submitted at the next meeting.

On behalf of the Committee appointed to confer with the Engineers' Club in regard to combining on the questions of rooms, meetings, lectures, etc., consisting of Messrs. Pagon, Whitman, and Janney, Mr. Pagon reported that the subject had been considered, but that at present no action seemed to be possible, and requested that the Committee be discharged, which, on motion, duly seconded, was done.

Mr. H. D. Bush addressed the meeting on the work of the General Committee, appointed in connection with the Naval Advisory Board, to investigate the industrial resources of the country. Mr. Bush, who is Chairman of the Board of Directors of this Committee for the State of Maryland, presented the task which confronts the Maryland Board in this investigation. The subject was discussed by Messrs. Crosby, Pitts, Smith, Janney, and others, and the following resolution, introduced by Mr. Crosby, was adopted unanimously:

"*Whereas,* a Board of Directors for the State of Maryland on Industrial Preparedness has been appointed by the Secretary of the Navy of the United States of America, and

"*Whereas,* said Board has been provided with no funds whatever for its necessary expenses, and

"*Whereas,* it seems to this Association proper that this Board should be relieved so far as possible from the financial burden of its work, which work further demands a considerable sacrifice of personal time and effort on the part of the individual members of the Board, therefore

"*Be it Resolved,* That in the interest of preparedness and with the desire to be of some aid to the members of the local Board in their patriotic work, the sum of fifty dollars ($50.00) be, and hereby is, appropriated from the balance in the treasury of this Association for the use of the Local Board of Directors on Industrial Preparedness; and

"*Be it Further Resolved,* That the Treasurer be, and hereby is, authorized and directed to pay over this amount of fifty dollars ($50.00) to the Treasurer, or other proper representative of said State Board of Directors on Preparedness."

On motion, duly seconded, the Secretary was instructed to communicate this action to the Board of Direction of the Society and to the Secretaries of the Local Associations.

The report of the Nominating Committee was presented, and, on motion, duly seconded, the following officers were declared elected: President, H. D. Bush; Vice-Presidents, John Biddle and C. W. Hendrick; Directors, R. Lloyd Chamberlaine, R. Keith Compton, J. W. Craig, W. W. Crosby, H. A. Lane, Ezra B. Whitman, and Henry G. Shirley.

President Bush then took the chair, and appointed Messrs. Pagon, Pitts, and Tilden a Committee to revise the Constitution, to report at the next meeting of the Association.

Mr. D. B. Goodsell, of New York City, addressed the meeting relative to the recent formation of a battalion of more than 400 volunteer engineers in New York.

Adjourned.

Cleveland Association, Organized 1914.

President, Robert Hoffmann; Secretary-Treasurer, George H. Tinker, Hickox Building, Cleveland, Ohio.

District of Columbia Association, Organized 1916.

President, A. P. Davis; Secretary-Treasurer, John C. Hoyt, U. S. Geological Survey, Washington, D. C.

Illinois Association, Organized 1916.

President, Onward Bates; Secretary-Treasurer, E. N. Layfield, 4251 Vincennes Avenue, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

President, W. B. Gregory; Secretary, E. H. Coleman, 920 Hibernia Building, New Orleans, La.

Northwestern Association, Organized 1914.

President, W. L. Darling; Secretary, Ralph D. Thomas, Minneapolis, Minn.

Philadelphia Association, Organized 1913.

President, Edward B. Temple; Secretary, W. L. Stevenson, 412 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

Portland, Ore., Association, Organized 1913.

President, J. P. Newell; Secretary, J. A. Currey, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1914.

President, J. A. Ockerson; Secretary-Treasurer, Gurdon G. Black, 34 East Grand Avenue, St. Louis, Mo.

The meetings of the Association are held at the Engineers' Club Auditorium. The Annual Meeting is held on the fourth Monday in November. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

San Diego Association, Organized 1915.

President, George Butler; Secretary-Treasurer, J. R. Comly, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

President, A. O. Powell; Secretary-Treasurer, Carl H. Reeves, 4722 Latona Avenue, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Northold Inn, 212 University Street.

(Abstract of Minutes of Meetings)

May 29th, 1916.—The meeting was called to order at 12.15 P. M., at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 16 members and guests.

The minutes of the meeting of April 24th, 1916, were read and approved.

Letters from the President and Secretary of the Society relative to co-operation by the Association with the Committee on Industrial Preparedness of the Naval Consulting Board; from S. W. Stratton, Chairman of the Thermometer Committee of the American Association for the Advancement of Science; and from the Board of Direction of the Society to the Philadelphia Association *in re* the letters of J. A. Ockerson, Past-President, Am. Soc. C. E., relative to the removal of Society Headquarters, respectively, were read and ordered filed.

The death of Mr. F. W. D. Holbrook of the Association was referred to briefly by President Powell, and after special reference to the death of Elmer L. Corthell, President of the Society, Mr. Ernest B. Hussey addressed the meeting, giving a brief outline of the life and work of Mr. Corthell and closing with a tribute of appreciation of his labors in the field of engineering, business, and finance.

After discussion by Messrs. Horrocks, Reeves, Powell, Hussey, and Jackson in reference to participation by engineers in the Preparedness Parade to be held in Seattle on June 10th, 1916, it was moved, seconded, and carried that the Association request the Committee on Industrial Preparedness to arrange for an Engineering Section in the Preparedness Parade in order that all engineers who so desired, might be given an opportunity to march in such parade.

Mr. William D. Wrightson, a Sanitary Engineer in the United States Public Health Service, addressed the meeting briefly on his experience at Vera Cruz, Mexico, during the occupancy of that city by the United States troops under Gen. Funston.

Adjourned.

June 26th, 1916.—The meeting was called to order at 12.15 P. M., at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 13 members and guests.

The minutes of the meeting of May 29th, 1916, were read and approved.

The President announced that he had appointed Messrs. J. I. Horrocks, Chairman, J. E. Shoemaker, and M. O. Sylliaasen, a Committee to serve in connection with the Preparedness Parade which had been held on June 10th, 1916.

The attention of members of the Association who are handling the work of the Industrial Census for the Naval Consulting Board was

called, by the President, to the necessity for securing all such data at the earliest possible moment.

The President also called attention to pages 317, *et seq.*, of the May, 1916, *Proceedings* of the Society, in regard to the question of the relations between the National Engineering Societies and the Local Associations of their members, and announced that such relations would be the subject for special discussion at the July meeting.

A letter from the National Conference on City Planning inviting the Association to appoint delegates to its Convention in Cleveland, Ohio, on June 5th-7th, 1916, was read by the Secretary, who announced that the letter had been received too late to comply with the request.

A letter from Governor Lister was read asking the Association to appoint three delegates to a conference to be held in Tacoma, on July 11th-12th, 1916, to consider and formulate a Water Code for the State of Washington. On motion, duly seconded, the President was authorized to appoint three delegates to attend the Conference.

On motion, duly seconded, it was also decided that the delegates of the Association favor a uniform Water Code for the State.

The President announced that his appointees to the Water Code Conference would undoubtedly be members of the Legislative Committee.

Mr. E. S. Jackson, of Goodings, Idaho, addressed the meeting, briefly describing the general idea and workings of the Idaho Water Code.

Adjourned.

Southern California Association, Organized 1914.

President William Mulholland; Secretary, W. K. Barnard, 701 Central Building, Los Angles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

President, Ulysses B. Hough; Secretary, A. D. Butler, Spokane, Wash.

Texas Association, Organized 1913.

President, John B. Hawley; Secretary, J. F. Witt, Dallas, Tex.

Utah Association, Organized 1916.

President, E. C. La Rue; Secretary-Treasurer, H. S. Kleinschmidt, 306 Dooly Building, Salt Lake City, Utah.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Concrete and Reinforced Concrete

May 5th, 1916.—The meeting was held at the House of the Society. Present, J. R. Worcester (Chairman), Robert W. Lesley, and Richard L. Humphrey (Secretary).

The Secretary presented a letter from the Secretary of the Society in reference to finances.

The Committee devoted the entire day to consideration of the preliminary draft of its final report.

The Committee agreed to hold its final meeting at the Hotel Traymore, Atlantic City, N. J., on Friday, June 30th, 1916, at 10.00 A. M., and to hold its next meeting at the House of the Society on June 6th, 1916.

June 6th, 1916.—The meeting was held at the House of the Society. President J. R. Worcester (Chairman), Olaf Hoff, Robert W. Lesley, Arthur N. Talbot, and Richard L. Humphrey (Secretary).

The Secretary presented a communication from the Secretary of the Society, calling the Committee's attention to the discussion, in the May, 1916, *Proceedings,* by Ernst F. Jonson, Assoc. M. Am. Soc. C. E., of the paper entitled "Method of Designing a Rectangular Reinforced Concrete Flat Slab, Each Side of Which Rests on Either Rigid or Yielding Supports", by A. C. Janni, M. Am. Soc. C. E., which was published in February, 1916, *Proceedings.*

The Committee devoted the entire day to the consideration of its final report, adjourning at 7.50 P. M., to meet on June 30th, 1916.

June 30th and July 1st, 1916.—The meetings were held at the Hotel Traymore, Atlantic City, N. J. Present, Joseph R. Worcester (Chairman), William K. Hatt, Robert W. Lesley, Arthur N. Talbot, and Richard L. Humphrey (Secretary).

The report of the Sub-Committee on Ways and Means was received, and on the request of the Chairman of the Sub-Committee, Messrs. Edward E. Hughes, of the American Society for Testing Materials, Olaff Hoff, and Robert W. Lesley, were appointed a committee to confer with the Society relative to finances.

The following motion was adopted:

"That a Committee on 'Editing', to consist of the Secretary and two other members of the Joint Committee, be appointed, which Committee shall be instructed to embody in the type now standing such changes as shall be adopted at this meeting of the Committee. This Committee shall be authorized to revise the table of contents, the running headings and cross references, and to correct typographical and grammatical mistakes and any inconsistencies, but not to change the meaning of any portion of the Report. After the type has been corrected, the Committee is to have duplicate proofs sent to each member of the Joint Committee, with the request that one copy be returned with any changes marked which may be discovered and with the member's written assent to the Report."

Messrs. Sanford E. Thompson and Henry H. Quimby were appointed as the two additional members of this Committee.

The Committee reconvened at 9.15 A. M. on July 1st, 1916, and spent the day and evening in completing the study of its final report, which, as amended, was adopted.

Verbal reports of the discussion of the work of the Committee at the Annual Convention of the Society at Pittsburgh, Pa., on June 27th, 1916, were considered, and the following resolution was adopted unanimously:

"*Whereas,* There has been brought to the attention of the Special Committee on Concrete and Reinforced Concrete the discussion of its work which took place at the Annual Convention of the American Society of Civil Engineers, in Pittsburgh, Pa., on June 27th, 1916, therefore,

"*Be It Resolved,* That the Secretary be instructed to request of the Board of Direction of the Society a copy of the stenographic report of this discussion."

Special Committee on Stresses in Railroad Track

May 10th and 11th, 1916.—Three sessions were held at the University of Illinois, Urbana, Ill. Present, A. N. Talbot (Chairman), A. S. Baldwin, W. J. Burton, Charles S. Churchill, W. C. Cushing, Paul M. La Bach, C. G. E. Larsson, G. J. Ray, and F. E. Turneaure. There were also present Messrs. Gennett and Morgan (representing Robert W. Hunt of the Committee), and F. F. Hanley (representing Earl Stimson of the American Railway Engineering Association).

The results of the experimental work carried out on the track of the Illinois Central Railroad, north of Champaign, Ill., during 1915, were discussed.

Tests on distribution of pressure through sand and broken stone ballast, made in the Laboratory of the University of Illinois, were presented and discussed.

Plans and methods for further tests were discussed at some length, and it was arranged to carry on additional tests on the Illinois Central Railroad to cover special points, and then to make the next tests on the Delaware, Lackawanna and Western Railroad.

The amount of funds necessary to complete the experimental work planned by the Committee was considered.

After the adjournment of the meeting, a number of the members observed an exhibition test on the track of the Illinois Central Railroad, north of Champaign, Ill., a Mikado locomotive being used.

Special Committee on Materials for Road Construction

June 17th, 1916.—The meeting was held at the House of the Society. Present, W. W. Crosby (Chairman), H. K. Bishop, A. W. Dean, Charles J. Tilden, George W. Tillson, and A. H. Blanchard (Secretary).

The minutes of the meeting of April 22d, 1916, were read and approved.

The outline and scope of the 1917 Report were discussed, and a section of the Report was adopted.

It was decided that the next meeting of the Committee should be held on June 26th, 1916.

June 26th, 1916.—The meeting was held at the Society House. Present, George W. Tillson (Chairman *pro tem.*), A. W. Dean, Nelson P. Lewis, Charles J. Tilden, and A. H. Blanchard (Secretary).

The minutes of the meeting of June 17th, 1916, were read and approved.

The sections of the 1917 Report relative to Stone Block and Wood Block Pavements were presented by Mr. Tillson, discussed, and tentatively adopted.

It was decided to hold the next meeting of the Committee on July 8th, 1916, at the House of the Society.

July 8th, 1916.—The meeting was held at the House of the Society. Present, George W. Tillson (Chairman *pro tem.*), Nelson P. Lewis, C. J. Tilden, and A. H. Blanchard (Secretary).

The minutes of the meeting of June 26th, 1916, were read and approved.

It was moved and carried that, in considering the different types of pavements, the Committee report only on pavements which have been in use for a sufficient length of time to demonstrate their economic value.

The sections of the 1917 Report relative to Brick and Slag Block Pavements, as presented by Mr. Lewis, and those pertaining to Bituminous Concrete Pavements, Types A, B, and C, Asphalt Block Pavements, and Sheet-Asphalt Pavements, as presented by Mr. Blanchard, were discussed and tentatively adopted.

On motion, the Committee adjourned to meet at the call of the Chairman about the middle of September, 1916.

Special Committee on Valuation of Public Utilities

July 3d-7th, 1916.—Thirteen sessions were held at the office of the Chairman in Boston, Mass. Present, F. P. Stearns (Chairman), C. S. Churchill, W. G. Raymond, H. E. Riggs, W. J. Wilgus, and J. P. Snow (Secretary *pro tem.*).

The part of the Report now in galley proof, covering the Glossary, Introduction, Fundamental Principles of Valuation, Property to be Included, Actual Cost, and Reproduction Cost, was thoroughly revised, and the remaining chapters on Reproduction of Land Holdings, Development Expense, Depreciation, and Intangible Values, were discussed, revised, and assigned to members to be put in shape for printing.

The meetings were adjourned on July 7th, 1916, to meet in September for further perfecting of the Report.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur= und Architekten=Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur= und Architekten=Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From May 2d to August 1st, 1916)

DONATIONS*

LEVEL SECTION TRANSPARENT SCALES FOR PLATE "A" PROFILES

For Graduation, Arch Masonry, and Iron Culverts. By F. W. Steber. Morocco, 9 x 3 in., illus., unpaged. No place, The Author, 1915. $2.50.

These scales have been made, it is stated, for estimating quantities from profiles made on Plate "A" profile paper. They are engraved on celluloid and bound in a form convenient for carrying in the pocket. For all ordinary excavation work and for transverse ground slopes up to 1 in 15, the scales, it is stated, are practically correct, and much steeper slopes can be safely estimated. For excavation and embankment there are three graduation tables with slopes of ½ : 1, 1 : 1, and 1½ : 1, as well as a table giving negative heights and quantities for various bases and slopes, with explanatory text. In the auxiliary tables the units are a prism of profile height with a base of 2 ft. and a triangle of profile height with a slope of ½ to 1. In the tables for arch culvert masonry the segmental arch is used, as suggested in Baker's "Masonry Construction". These tables are for arches of 6, 8, 10, 12, 14, and 16 ft., based on a 20-ft. base embankment with a slope of 1½ to 1. In these tables the scale of quantities is given in cubic yards and shows nothing below a 3-ft. cover over the crown of the arch. The tables for medium weight cast-iron culvert pipe include 24, 30, 36, 42, 48, 54, and 60-in. pipe, based on a 20-ft. base embankment with slopes of 1½ to 1. The scale of quantities for these pipes is in tons of 2 000 lb. and shows nothing under a cover of 3 ft. over the top of the pipe.

THE PORT OF BOSTON:

A Study and a Solution of the Traffic and Operating Problems of Boston, and Its Place in the Competition of the North Atlantic Seaports. By Edwin J. Clapp. Cloth, 9 x 6 in., illus., 12 + 402 pp. New Haven, Yale University Press, 1916. $2.50.

The preface states that this book is the outgrowth of a private report, made to the Directors of the Port of Boston, on the traffic situation in Boston. The subject-matter, as stated in the secondary title, covers not only the traffic problems, but also those of operation, that is, the cost and facility of terminal operations on which depend the terminal service and charges. The author, it is said, has stated clearly the problems of the port and has indicated the main lines to be followed in their solution, and although the title reads "Port of Boston", the book, it is stated, has not been written for Boston alone, much attention having been given throughout the text to the theory of port charges and operations, and the practices of other Atlantic ports relative to belt lines, lighterage, elevator charges, and port industries, are also cited. The Contents are: Part I, Traffic: On the Meaning of Port Development; A, The Terminal Problem; B, Inland Rates; C, A Solution of the Traffic Problem; D, The Coastwise Traffic Situation. Part II, Operation: A, Co-Ordinating Rail and Oversea Carriers; B, Co-Ordinating Rail and Coastwise Carriers; Index.

THE TWO BOOKS ON THE WATER SUPPLY OF THE CITY OF ROME

Of Sextus Julius Frontinus, Water Commissioner of the City of Rome, A. D. 97: A Photographic Reproduction of the Sole Original Latin Manuscript, and Its Reprint in Latin; Also a Translation into English, and Explanatory Chapters. By Clemens Herschel, President, Am. Soc. C. E. Second Edition. Cloth, 11½ x 8½ in., illus., 24 + 23 + 296 pp. New York, London, Bombay, and Calcutta, Longmans, Green, and Co., 1913. $6.50.

The first edition of this work was published in 1899, and this, the second, edition was issued in June, 1913. The object of the book, as stated in the Introduction, is to present for the edification of the Engineering Profession a translation of the

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* Unless otherwise specified, books in this list have been donated by the publishers.

work of Sextus Julius Frontinus, the study of which has been the author's pastime and hobby for a number of years. As stated in the title, the subject-matter consists of a photographic reproduction of the original manuscript which is in the Library of the Benedictine Monastery at Montecassino, Italy, where the author journeyed in 1897 to examine it. This is followed by the translation, the Latin and English being on opposite pages, of Frontinus' work which is a history of the conditions relative to the water supply of Rome, its sources, reservoirs, distribution systems, operation, maintenance, laws, etc. The translation is followed by explanatory chapters by the author, in which he describes and illustrates in detail, from the viewpoint of a hydraulic engineer, the work accomplished by Frontinus. The Contents are: Introduction; Photographic Reproduction of the Montecassino Codex; Ivlii Frontini de Agris Urbis Romae Libri II; The Two Books on the Water Supply of the City of Rome of (Sextus) Julius Frontinus; Index of Proper Names to the "II Books": Explanatory Chapters: Some Account of the Life and Works of Sextus Julius Frontinus; Springs, Wells, and Rain-Water Cisterns in Ancient Rome; Frontinus' Description of the Nine Aqueducts; Aqueduct Building, and the Waters of the Aqueducts; Measuring Water, A. D. 97; Hydraulics After Frontinus' Time; Arithmetic, A. D. 97, Among the Romans; The Distribution System; Operation; Maintenance and Repairs; The Law of Water-Rights in Rome, A. D. 97; The Character of the Water Commissioner, Sextus Julius Frontinus; Appendix to Chapter XI (Water Rights); Index to Explanatory Chapters.

MASONRY DAM DESIGN

Including High Masonry Dams. By Charles E. Morrison and Orrin L. Brodie, M. Am. Soc. C. E. Second Edition, Revised and Enlarged. Cloth, 9¼ x 6 in., illus., 9 + 276 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.50.

The third-year students in the Department of Civil Engineering at Columbia University are required, it is stated, as part of their class work, to submit a design of a masonry dam, and as an aid in this problem they have been furnished, it is said, with copies of "Notes on the Theory and Design of High Masonry Dams", by William H. Burr, M. Am. Soc. C. E., which is based on the method of calculating the cross-sections of high masonry dams devised by Edward Wegmann, M. Am. Soc. C. E. In his treatment of the subject, however, Mr. Wegmann has omitted the effects of uplift, ice thrust, etc., on such dams, and in this book, it has been the aim of the authors to supply these omissions, together with a brief statement regarding recent investigations relative to more accurate determination of variations of stress in masonry dams. In this second edition the authors, it is said, have amplified some of the features which, in the first edition, were only touched on. Chapters on the Overfall and Arched types of masonry dams have been added, together with cross-sections of a selected series of masonry dams arranged chronologically for the purpose, it is stated, of comparison and to show the development of such dams from the massive Spanish type to that of the present. Low and medium-sized dams may also be designed, it is said, according to the theory and methods given, general expressions having been included whenever possible. The formulas relating to uplift, ice thrust, etc., have been used in part, it is stated, in connection with the design of the large dams for the new water supply of the City of New York and the computations for the design of high masonry dams are appended to facilitate the ready comprehension and application of the formulas presented. The Contents are: Upward Pressure and Ice Thrust; Preliminary Considerations; Development of Formulæ; Investigation Formulæ; The Design of a Masonry Dam; Weir or Overfall Type of Dam; The Arch Dam; Recent Considerations of the Condition of Stress in a Masonry Dam; Appendix I, Derivation of Cantilever Equations; Appendix II, Derivation of Arch Equations; Cross-Sections of Existing Masonry Dams; Index.

HYDRAULIC FLOW REVIEWED:

A Book of Reference of Standard Experiments on Pipes, Channels, Notches, Weirs, and Circular Orifices, Together with New Formulæ Relating Thereto. By Alfred A. Barnes. Cloth, 9¾ x 6¼ in., illus., 11 + 158 pp. London, E. & F. N. Spon, Limited; New York, Spon & Chamberlain, 1916. $4.50. (Donated by Spon & Chamberlain.)

The author having found, in his work, great diversity in the values of the coefficients generally used in discharge formulas, investigated the subject and made a series of experiments from which he evolved the new and simple formulas presented in this book. He has shown, it is stated, that, given the physical conditions, the value of the coefficient in his formulas depends only on the type or class of pipe, channel, etc., and does not vary with either dimensions or gradient, and

also that such a formula or equation can be found to fit, with great accuracy, every diameter and hydraulic gradient of pipe of any well-known size and every size and gradient of channel of fully described character. The tables in the second part of the book also show, it is said, that a similar equation or formula can be found, which represents with greater accuracy the flow through orifices, weirs, and notches. All the published experiments used for determining the author's formulas have been tabulated and are contained in the Appendices. The formulas are given at the head of the tables, and the calculated values corresponding to the experimental values have been scheduled, as well as the percentages of difference. Throughout the investigations, no assumptions whatever have been made, the author, it is said, having used only those results actually obtained in reliable experiments by various authorities, and, to that extent, the formulas must be regarded as empirical. Logarithms have been used in calculating the results and such use is described in detail in the text, a few examples being given on the plates at the end of the book. English measurements only have been used, and, in building up the formulas, graphical methods have been applied. A short list of standard books on the subject is included. The Contents are: Pt. I. Determination of the Coefficients in the Logarithmic Formula for the Flow of Water in Pipes and Channels; Pt. II, The Measurement of Water by Means of Triangular Notches, Weirs and Circular Orifices; The Abolishment of the Varying Coefficient; Triangular Notches; Rectangular Weirs, with Full End Contractions; Rectangular Weirs, without End Contractions; Formulæ for the Two Types of Weirs Contrasted; Circular Orifices; Conclusion and Summary; Working Tables and Diagrams; Appendix: The Discharge of the Rochester Pipe Line in 1876; Index.

HYDRAULICS.

By R. L. Daugherty. Cloth, 9¼ x 6 in., illus., 14 + 267 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $2.50.

This book, it is stated, is intended primarily for students who are required to cover a wide field in hydraulics within a limited time. The author's main idea is, therefore, to present, it is said, only fundamental principles as clearly and concisely as possible. The arrangement and presentation of the subject-matter have been carefully considered with the view of connecting one part with another, and a number of diagrams and photographs have been used to illustrate the text in order, it is said, to give the student a clearer idea of the characteristics of the machines described. The treatment of the subject throughout the book is stated to be general, special cases being included only when necessary to illustrate some general principle or to make it clearer. The theory, general appearance, construction, and arrangement of turbines and centrifugal pumps are discussed, together with the principles of their operation, but discussion of their design has been omitted as not within the scope of this work. At the end of each chapter, the author has included problems, many of which have been taken, it is stated, from actual practice, and the solution of those involving the flow of water is made, it is said, to depend on applications of Bernoulli's theorem. Only sufficient information on experimental coefficients and empirical factors is included, it is stated, to give the student a correct idea of the range of values and the considerations which enter into the choice of a suitable value for a given case. The Chapter headings are: Introduction; Intensity of Pressure; Hydrostatic Pressure on Areas; Applications of Hydrostatics; Hydrokinetics; Applications of Hydrokinetics; Flow Through Pipes; Uniform Flow in Open Channels; Hydrodynamics; Description of the Impulse Wheel; Description of the Reaction Turbine; Water Power Plants; Theory of the Impulse Wheel; Theory of the Reaction Turbine; Turbine Laws and Factors; The Centrifugal Pump; Appendix: Tables; Index.

BRIDGE ENGINEERING.

By J. A. L. Waddell, M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 2 v. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $10.00. (Donated by the Author.)

In these volumes which, it is stated, are in a certain sense a record of the author's lifework, it has been his aim to give all the information concerning every branch of bridgework, which he has been able to accumulate during a practice of 40 years. This work, it is stated, is not a new edition of the author's previous book, "De Pontibus", but portions of the latter, revised and brought up to date, have been included. He has also quoted freely from papers presented by himself before various scientific societies. The preface states that the work should prove useful to all engineers engaged in the design and construction of bridges, especially the younger and less experienced men, for not only are the principles of design described and illustrated, but such matters as loads, intensities, materials, esthetics, economics, and business methods, are treated exhaustively. Various tables and diagrams are also included, by which close estimates of costs may be made for

nearly every kind of bridge and of any length and size, regardless of the traffic carried. Data are also given for determining, at least approximately, the weights of metal required by the use of alloy steels of various elastic limits for spans of unprecedented width and length. The practical treatment of the various stresses for bridges is explained, as well as standard methods of computing for deflections and proportioning for camber. In connection with the statement of the first principles of design, their applications, etc., contained in Chapter XV, which, the author states, is the most important chapter in the book, the general detailing of all kinds of fixed spans is described. Movable spans are discussed only in a general and descriptive manner in Chapters XXVIII to XXXI, inclusive. The various methods of protecting the metal work of bridges are treated at length, as well as those for the protection of drawbridges, etc. In Chapter XXXVII, the practice of the design and construction of reinforced concrete bridges is described in detail, and specifications for such bridges are also included, but the theory is omitted, except certain formulas which have been established in the author's office, for the reason that the subject is fully discussed in various other books, the titles of which are given. All kinds of substructures, such as foundations, coffer-dams, piles, piers, etc., are described and illustrated in Chapters XXXVIII to XLV, inclusive, including specifications and explanations of how, when, and where to adopt the different types. Chapters XLVI to LI, inclusive, and Chapter LIV, are devoted to work preliminary to the actual design of bridges, such as surveys, borings, Government requirements, hydrographic surveys, etc., and the esthetics and true economy in design are fully discussed in Chapters LII and LIII. Quantities of materials of various kinds used in bridge construction are given in Chapters LV and LVI, and subsequent chapters (LVII, and LXVIII to LXX, inclusive) relate to the preparation of estimates, specifications, contracts, and reports. A thorough description of the various phases of office practice is given in Chapter LVIII, and, in Chapter LIX, the inspection of materials of all kinds is discussed in detail. Chapters LX to LXV, inclusive, cover all matters relative to field engineering, such as triangulation, erection, falsework, maintenance, repairs, etc. Preliminary to his chapter on Specifications, the author devotes Chapters LXVI and LXVII to the status of bridge building and bridge failures and their lessons. Chapters LXXI to LXXV, inclusive, relate to business matters connected with engineering, and the ethics of bridge engineering are discussed in Chapters LXXVI and LXXVII. Complete specifications governing the design of superstructures of all kinds for bridges, trestles, viaducts, and elevated railroads, with a clause index for computers, are given in Chapter LXXVIII, and Chapter LXXIX contains complete specifications governing the manufacture and erection of superstructures, substructures, approaches, and all accessory works for bridges, trestles, viaducts, and elevated railroads. There is also a clause index to this chapter to facilitate the use of the specifications. Chapter LXXX contains, it is said, the most complete glossary of technical terms used in bridgework, that has ever been compiled. In addition to the General Index, the author has given separate lists of the various illustrations and tables, arranged by chapter and number. Although not intended as a textbook for engineering students, it is stated that the volumes are well adapted to supplement the standard works used in the classroom, and they may also serve for general reference in technical and public libraries.

THE THEORY AND PRACTICE OF MODERN FRAMED STRUCTURES

Designed for the Use of Schools and for Engineers in Professional Practice. By the Late J. B. Johnson, C. W. Bryan, and F. E. Turneaure, Members, Am. Soc. C. E. Part III, Design. Ninth Edition, Rewritten by F. E. Turneaure and W. S. Kinne. Cloth, 9¼ x 6 in., illus., 12 + 486 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $4.00.

The preface states that this book is the third of a series of three volumes constituting a complete re-writing of "Modern Framed Structures", first published in 1893, and is intended primarily, it is said, as a textbook on bridge design, although some of the general features, it is hoped, may be of interest and value to the practicing engineer. In this edition, certain topics, such as those relating to building construction, elevated tanks, swing bridges, and trestles, have been omitted, owing, it is stated, to the development and specialization in structural engineering. The subject-matter includes first a discussion of certain topics of fundamental importance in bridge design, which is covered in Chapters I to VII, inclusive. This is followed, in Chapters VIII to XI, by detailed analysis and design of the several structures, illustrating the principles discussed in the preceding chapters. There are also Appendices containing general specifications for steel railroad bridges, tables of frequently used standards, and a discussion of the mechanics of unsymmetrical bending. The Contents are: Styles of Structures and Determining Conditions; Working Stresses—Tension Members; Compression Members; Combined Direct and Bending Stresses—Secondary Stresses; Riveted Joints; Plate Girder Bridges; Design of Truss Bridges; Design of a Pin-Connected Railway Bridge,

Riveted Trusses; Design of a Riveted Highway Bridge; Design of Steel Roof Trusses; Appendix A, General Specifications for Steel Railway Bridges; Appendix B, Tables and Standards; Appendix C, Unsymmetrical Bending.

ENGLISH AND AMERICAN TOOL BUILDERS.

By Joseph Wickham Roe. Cloth, $9\frac{1}{2}$ x $6\frac{1}{2}$ in., 15 + 315 pp. New Haven, Yale University Press, 1916. $3.00.

The purpose of this book, part of which has appeared in the *American Machinist*, is to bring out, the preface states, the importance of the work and influence of the great tool builders whose art has been fundamental to all modern industrial arts, for without machine tools, it is said, modern machinery could not be built. The author, it is stated, has tried to trace the origin and rise of tool building in America and describe something of its spread in recent years. He has confined himself, therefore, it is said, to the main lines of influence in tool building and to the personalities and cities which have been most closely identified with it. At the end of the book, there has been included a bibliography on Tool Building, and it is hoped that the volume will stimulate interest in the lives and work of the pioneer tool builders to whom the Engineering Profession owes so much. The Chapter Headings are: Influence of the Early Tool Builders; Wilkinson and Bramah; Bentham and Brunel; Henry Maudslay; Inventors of the Planer; Gearing and Millwork; Fairbairn and Bodmer; James Nasmyth; Whitworth; Early American Mechanics; The Rise of Interchangeable Manufacture; Whitney and North; The Colt Armory; The Colt Workman—Pratt & Whitney; Robbins & Lawrence; The Brown & Sharpe Manufacturing Company; Central New England; The Naugatuck Valley; Philadelphia; The Western Tool Builders; Appendix A; Appendix B, The Jennings Gun; A Partial Bibliography on Tool Building; Index.

INDUSTRIAL USES OF FUEL OIL.

By F. B. Dunn. Cloth, $8\frac{1}{2}$ x $5\frac{1}{2}$ in., illus., 235 pp. San Francisco, Technical Publishing Company, 1916. $3.00.

This book, it is stated, is intended to be a practical exposition of the use of fuel oil for various industrial purposes, and has been written for the use of practical men. The subject-matter contains, it is said, brief descriptions of many of the manufacturing processes in which oil may be used as fuel, and these descriptions are followed, in each case, by detailed directions for furnace and boiler arrangement as well as approved methods of operation. From a study of the text, the engineer, architect, plant superintendent, manager, fuel oil salesman, and efficiency expert should be able to judge, it is said, as to the applicability of fuel oil to their purposes, and Chapters XVI and XVII, on Furnace Efficiency and Tests, in which descriptions of how boiler losses may be checked and true efficiency determined, should prove of value, it is stated, to operating engineers. The Contents are: Oil as a Fuel; Oil Storage and Pumping Systems; Boiler Furnace Arrangement; Oil Burners; Oil Strainers and Heaters; Oil in the Clay, Lime and Cement Industries; Oil in the Glass Industry; Oil Burning Locomotives; Oil in the Sugar and Rubber Industries; Smelting Furnaces Fired with Oil; Metallurgical and Shop Furnaces; Oil in the Steel Industry; Fuel Oil for Naval and Maritime Purposes; Fuel Oil for Domestic Purposes; The Rotary System of Burning Oil; Furnace Efficiency and Combustion; Tests and Reports; Oil for Gas Making; Index.

CONCRETE CONSTRUCTION FOR RURAL COMMUNITIES.

By Roy A. Seaton. (Agricultural Engineering Series.) Cloth, $8\frac{1}{4}$ x $5\frac{3}{4}$ in., illus., 11 + 223 pp. New York and London, McGraw-Hill Book Company, Inc., 1916. $2.00.

Most of the books on concrete construction now available have been written, it is stated, for the engineer, or are in the form of bulletins dealing chiefly with the uses to which concrete can be put in rural communities, without including a systematic treatment of the fundamental principles governing such use. The extension of the use of concrete to farms and rural communities generally, has made a knowledge of its valuable properties and the proper methods of using it highly desirable, and has developed, it is said, a need for a textbook, such as this volume, which treats of the essential features of concrete construction in a thorough but simple manner. In preparing this volume, the author, it is stated, has endeavored to make it suitable for use as a textbook in a brief course on concrete construction for agricultural and other students when accompanied by laboratory exercises and field construction, and, for that reason, he has included Chapter II, on Cement Specification and Tests, and Chapter VIII, on Strength of Reinforced Concrete, which are not necessary to the use of the non-technical workman. The Contents are: Introduction; Part I, Materials: Cements and Limes; Cement Specifications

and Tests; Aggregates. Part II, Plain Concrete: Proportions and Quantities of Materials; Construction of Forms; Mixing and Handling Concrete. Part III, Reinforced Concrete: General Principles; Strength of Reinforced Concrete. Part IV, Miscellaneous Matters: Concrete Surface Finishes; Stucco and Plaster Work; Waterproofing and Coloring Concrete; Casting in Molds. Part V, Typical Applications of Concrete: Sidewalks, Floors and Roads; Tanks, Cisterns, and Silos; Small Highway Bridges and Culverts; Index.

THE ENGINEER IN WAR

With Special Reference to the Training of the Engineer to Meet the Military Obligations of Citizenship. By P. S. Bond, M. Am. Soc. C. E. Reprinted, with Revisions and Additions, from the *Engineering Record.* Roan, 7½ x 5 in., illus., 15 + 187 pp. New York, McGraw-Hill Book Company, Inc.; London, Hill Publishing Co., Ltd., 1916. $1.50.

In presenting this volume to the Engineering Profession, the author, it is said, does not intend to provide a treatise on military field engineering, on which subject many textbooks and manuals have been written. The subject-matter of this book consists, as stated, of a brief outline of the relation of engineering to the conduct of war and the adaptation of the principles and practices of civil engineering thereto. Although intended primarily for the engineer and contractor, it is hoped that the volume may prove of interest to all who contemplate serving their country in case of need. There is included a bibliography on military subjects issued by the United States War Department, to which has been added a list of textbooks, and there is also a glossary of military terms used in the text. The Contents are: The Military Policy of the United States; General Duties of the Military Engineer and Economics of Military Engineering; Tools and Equipment Employed in Military Engineering; Stream Crossings; Military Roads; Field Fortification and Siege Operations; Military Demolitions; Military Reconnaissance, Sketching, and Surveying; Military Sanitation; The Mobilization of Material Resources; How May the Engineers and Contractors of America Prepare to Meet the Military Obligations of Citizenship?; Bibliography; Glossary of Terms; Index.

THE AMERICAN ROAD:

A Non-Engineering Manual for Practical Road Builders, Treating of the Construction, Administration, and Economics of Improved Earth Roads. By James I. Tucker. Cloth, 7½ x 5 in., illus., 12 + 235 pp. Norman, Okla., The Author, 1916.

The preface states that this book has a double purpose, namely, to present to the non-technical reader the simple facts which underlie and are essential to sound road work, particularly in the development of country roads in the United States, and to furnish material for a brief correspondence course for road-builders. The subject-matter deals, it is said, wholly with "cheap" roads, but the necessity of applying sound engineering principles to such roads is emphasized. Road economics and administration and the convict question are briefly considered, followed by a short discussion on location, grades, drainage, etc. Methods of construction and maintenance of earth, sand-clay, "top-soil", and gravel roads, as developed in the various States, are discussed in detail, with their costs, as well as the materials which have been used successfully in such roads. There is also an outline treatment and elementary discussion of such road structures as larger culverts and bridges, and a chapter on legislation in which the legislative steps necessary to the most economical expenditure of public money on public roads. The author, it is said, hopes that this book will prove helpful to engineers, county boards, county commissioners and other road officials and that it will lead to the construction and maintenance of the greatest number of good roads at the least possible cost. The contents are: General Conditions and Preliminary Studies; Road Economics; Road Administration; Convicts and Road Work; Earth Road Construction; Cost Accounting and Earthwork; Earth Road Maintenance; Waterways; Bridges; Road Finance; Stone Roads; Gravel Roads; Sand-Clay Roads; Road-Building with Oils; Needed Legislation; Index.

CITY PLANNING:

A Series of Papers Presenting the Essential Elements of a City Plan. Edited by John Nolen. (National Municipal League Series.) Cloth, 7¾ x 5¼ in., illus., 26 + 447 pp. New York and London, D. Appleton and Company, 1916. $2.00.

Although some attention is devoted to problems of municipal organization and administration in their relations to city planning, this book, it is stated, is con-

cerned primarily with the nature, purposes and methods of such planning. The subject-matter consists of a collection of essays on the subject by sixteen men of recognized knowledge and practical experience in that particular part of city planning of which they write. These essays, it is said, form a carefully related series which, taken together, cover the essential elements of a city plan, presenting a convenient summary of American practice and an embodiment of good methods and practice in such work. At the end of each chapter there is appended a selected list of books and articles on the subject discussed, and, at the end of the book, there is a brief bibliography of the most authoritative works and papers on the subject of city planning as a whole. The text is fully illustrated, and, following the preface, are brief biographical sketches of the contributors. The Contents are: Introduction, by Frederick Law Olmsted; the Subdivision of Land, by John Nolen; Public Control of Private Real Estate, by Frank Backus Williams; Local and Minor Streets, by Edward Henry Bouton; Public Buildings and Quasi-Public Buildings, by Edward H. Bennett; Neighborhood Centers, by Arthur Coleman Comey; General Recreation Facilities, by J. Horace McFarland; Park Systems, by John Nolen; Water Supply and the City Plan, by Caleb Mills Saville; Non-Navigable Waters, by Arthur A. Shurtleff; Navigable Waters, by E. P. Goodrich; Railroads and Industrial Districts, by George R. Wadsworth; Transportation and Main Thoroughfares and Street Railways, by Benjamin Antrim Haldeman; The Effect of Rapid Transit on the City Plan, by John Vipond Davies; Residential and Industrial Decentralization, by James Ford; Fundamental Data for City Planning Work, by George Burdett Ford; City Financing and City Planning, by Flavel Shurtleff; City-Planning Legislation, by Charles Mulford Robinson; General Bibliography; Index.

THEORY OF ERRORS AND LEAST SQUARES:

A Textbook for College Students and Research Workers. By LeRoy D. Weld. Cloth, $7\frac{1}{2}$ x 5 in., illus., 12 + 190 pp. New York, The Macmillan Company, 1916. $1.25.

Few branches of mathematics, it is stated, have wider applicability to general scientific work than the Theory of Errors and there are few mathematical implements capable of greater usefulness to the research worker than the Method of Least Squares, but the student, it is said, is rarely given the opportunity of acquiring facility along these lines. This volume, the preface states embodies material used by the author as lecture notes during the last 12 years, and the subject is presented herein, it is said, in such a simple and concise form as to be useful not only as a textbook for the student but also as a handy reference for the research worker. The illustrative examples and problems contained in the text are drawn from various branches of science, suggesting, it is said, a wide range of possible application, but no attempt has been made at an exhaustive treatment. Some of the special methods used by expert computers have been omitted purposely, it is stated, and a few of the more complicated mathematical discussions are included in the Appendix for the convenience of the student, and referred to in the text. The Chapter headings are: On Measurement; On the Occurrence and General Properties of Errors; On Probabilities; The Error Equation and the Principle of Least Squares; On the Adjustment of Indirect Observations; Empirical Formulas; Weighted Observations; Precision and the Probable Error; Appendix; Supplementary Notes.

OXY-ACETYLENE WELDING AND CUTTING

Electric, Forge and Thermit Welding, Together with Related Methods and Materials Used in Metal Working and the Oxygen Process for Removal of Carbon. By Harold P. Manly. Cloth, $6\frac{3}{4}$ x $4\frac{1}{2}$ in., illus., 215 pp. Chicago, Frederick J. Drake & Co., 1916.

As stated in the secondary title, the author's aim, in this book, has been to cover not only the several processes of welding, but also other and closely allied processes which form a part of the subject of joining metal to metal with the aid of heat. He has also discussed, it is said, other operations which precede or follow the actual joining of the metal parts, the purpose of which is to add or retain certain desirable qualities in the materials being handled, such as annealing, tempering, hardening, heat treatment, and the restoration of steel. Much practical information is also given, it is stated, on the uses and characteristics of the various metals, on the production, handling, and use of the gases and other materials which are part of the equipment, and on the tools and accessories for the production and handling of these metals. All theoretical, historical, and similar matter not absolutely necessary to the practical workman has been eliminated, it is said, the descriptions being limited to present-day methods and practice, including the application of the rules laid down by insurance underwriters governing this work, as well as instructions for the proper care and handling of generators, torches, and materials found in the shop. Although the volume is small in size, the

practical workman, it is stated, will find all the data necessary to a knowledge of both principle and practice, preparation and finishing of the work, of both large and small repair work, and of the manufacturing methods used in metal working. The Contents are: Metals and Alloys-Heat Treatment; Welding Materials; Acetylene Generators; Welding Instruments; Oxy-Acetylene Welding Practice; Electric Welding; Hand Forging and Welding; Soldering, Brazing, and Thermit Welding; Oxygen Process for Removal of Carbon; Index.

MACRAE'S BLUE BOOK, 1916:

America's Greatest Buying Guide. Cloth, 11½ x 8½ in., illus., various pagings. Chicago and New York, MacRae's Blue Book Company, 1916. $10.00.

In a secondary title, it is stated that this book is used by the mechanical, engineering, and purchasing departments of the steam and electric railways of North America, by mines, contractors, iron and steel industries, municipalities, shipbuilders, the United States and foreign Governments, and others. The subject-matter consists of a Catalogue Section in which the catalogues of various manufacturers have been collated in condensed form; an Address Section containing an alphabetical list of firms advertising in this book and also an alphabetical list of their representatives; a Classified Material Section in which are listed in alphabetical order, under 9 000 classifications, the names and addresses of various manufacturers of railway supplies, iron and steel products, and building construction materials; a Trade Name Section arranged alphabetically; a Miscellaneous Data Section which is preceded by an alphabetical index, containing rules and tables of special interest to the man who specifies or buys railway and building materials, or iron and steel products; a Standard List Price Section, also preceded by an alphabetical index, containing standard list prices for building materials and iron and steel products; and a Net Discount Computer.

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BY PURCHASE

Good Roads Year Book, 1916. Fifth Edition. American Highway Association, Washington, D. C.

The Construction of Gas Works Practically Described. By Walter Ralph Herring. London, 1892.

Coal and Coke. By Frederick H. Wagner. New York, 1916.

A Manual for Health Officers. By J. Scott MacNutt, with a Foreword by William T. Sedgwick. New York, 1915.

Geology. By Thomas C. Chamberlin and Rollin D. Salisbury. 3 Vol. New York, 1909.

English Public Health Administration. By B. S. Bannington; Introduction by Graham Wallas. London, 1915.

The Practical Design of Steel-Framed Sheds. By Albert S. Spencer. New York, 1915.

Harper's Hydraulic Tables for the Flow of Water in Circular Pipes Under Pressure, Timber Flumes, Open Channels, and Egg-Shaped Conduits, with Much Accessory Information. By Joseph Harper. New York and London, 1916.

The Sampling and Chemical Analysis of Iron and Steel. By O. Bauer and E. Deiss. Authorized Translation from the German, by William T. Hall and Robert S. Williams. New York and London, 1915.

Liquid Air, Oxygen, Nitrogen. By Georges Claude. English Edition Corrected and Brought up to Date by the Author. Translated by Henry E. P. Cottrell, with a Preface by D'Arsonval. London, 1913.

The Metallography and Heat Treatment of Iron and Steel. By Albert Sauveur. Second Edition. Cambridge, Mass., 1916.

The Principles and Practice of Iron and Steel Manufacture. By Walter Macfarlane. Third Edition. New York and London, 1912.

Flight Without Formulæ: Simple Discussions on the Mechanics of the Aeroplane. By Commandant Duchene. Translated from the French by John H. Ledeboer. New York and London, 1914.

The Testing of Materials of Construction: A Text-Book for the Engineering Laboratory and a Collection of the Results of Experiment. By William Cawthorne Unwin. Third Edition. New York and London, 1910.

The Telephone and Telephone Exchanges: Their Invention and Development. By J. E. Kingsbury. New York and London, 1915.

Factory Administration and Accounts: A Book of Reference with Tables and Specimen Forms, for Managers, Engineers, and Accountants. By Edward T. Elbourne. With Contributions on the General Problem of Industrial Works Design by Andrew Home-Morton and Financial Accounts by John Maughfling. New York and London, 1914.

An Introduction to the Study of Physical Metallurgy. By Walter Rosenhain. New York, 1915.

Institution of Mining and Metallurgy: Transactions; Vol. 24; 1914–15. London, 1915.

The Plenum or Propulsion System of Heating and Ventilation. By Harold Griffiths. London.

Autogenous Welding and Cutting. By Theodore Kautny. Translated by the Author and James F. Whiteford. New York and London, 1915.

Poor's Manual of Public Utilities, 1916: Street Railway, Gas, Electric, Water Power, Telephone and Telegraph Companies. Fourth Annual Number. New York.

Railway Expansion in Latin America: Descriptive and Narrative History of the Railroad Systems of Argentina, Peru, Venezuela, Brazil, Chile, Bolivia, and All Other Countries of South and Central America. By Frederic M. Halsey. New York, 1916.

Wireless Telegraphy. By J. Zenneck. Translated from the German by A. E. Seelig. New York and London, 1915.

Forschungsarbeiten auf dem Gebiete des Ingenieurwesens. Herausgegeben vom Verein Deutscher Ingenieure. Heft 183. Berlin, 1916.

Chemistry in the Service of Man. By Alexander Findlay. New York and London, 1916.

American Society of Municipal Improvements: Proceedings of the Twenty-Second Annual Convention Held at Dayton, Ohio, October 12th, 13th, 14th, and 15th, 1915. Indianapolis, 1916.

Public Utilities Reports Annotated, 1916 B: Containing Decisions of the Public Service Commissions and of State and Federal Courts. Rochester, N. Y.

Digest of Public Utilities Reports Annotated for the Year 1915, Including Vol. 1915 A–1915 F. Rochester, N. Y., 1916.

SUMMARY OF ACCESSIONS

(From May 2d to August 1st, 1916)

Donations (including 1 115 duplicates)	2 073
By purchase	30
Total	2 103

MEMBERSHIP

(From May 5th to August 3d, 1916)

ADDITIONS

MEMBERS		Date of Membership.
ACRES, HENRY GIRDLESTONE. Hydr. Engr., Hydro-Elec. Power Comm. of Ontario, 111 Spadina Rd., Toronto, Ont., Canada		April 18, 1916
ALLEN, WALTER HENRY. Cons. Engr., 111 West Monroe St., Chicago, Ill	Assoc. M. M.	Jan. 3, 1911 June 24, 1916
ANDREWS, ROBERT EDMUND. Hydr. Engr., Committee on Fire Prevention, National Board of Fire Underwriters, 606 Grant Pl., Bay City, Mich	Assoc. M. M.	Jan. 2, 1912 June 24, 1916
ATWOOD, EDWARD FRANKLIN. Constr. Engr., John T. Scully Foundation Co., 118 First St., Cambridge (Res., 131 Bellingham Ave., Revere), Mass	Assoc. M. M.	June 5, 1907 Mar. 14, 1916
BALDWIN, LEWIS WARRINGTON. Gen. Mgr., Cent. of Ga. Ry., Savannah, Ga		April 18, 1916
BEAL, GEORGE SAFFORD. Div. Engr. of Dams, Water Supply Comm. of Pennsylvania, Telegraph Bldg., Harrisburg, Pa	Assoc. M. M.	June 6, 1906 June 24, 1916
BILLINGSLEY, JAMES WARTELLE. Cons. Engr., Interstate Bank Bldg., New Orleans, La.	Assoc. M. M.	May 6, 1908 June 24, 1916
BRENTON, WILLIAM HENRY. Field Engr., Interstate Commerce Comm., Div. of Valuation, Room 408, Wells Fargo Bldg., Portland, Ore		April 18, 1916
BURT, AARON MOULTON. Chf. Engr. of M. of W., N. P. Ry., St. Paul, Minn		May 31, 1916
BUSH, PHILIP LEE. Chf. Engr., California Fruit Canners Assoc., 120 Market St., San Francisco, Cal	Assoc. M. M.	Sept. 6, 1906 May 31, 1916
CARROLL, JAMES EDWARD. Supt., Constr. and Repairs, Dept. of Public Works, 1682 Lincoln Ave., St. Paul, Minn		June 23, 1916
CASTLEMAN, FRANCIS LEE. Engr. in Chg., Eng. Dept., Am. Bridge Co., Pencoyd, Pa		June 23, 1916
CONLEY, CLYDE GREYSON. Contr. Engr. and Secy., The Mt. Vernon Bridge Co., Mt. Vernon, Ohio	Assoc. M. M.	Aug. 31, 1909 May 31, 1916
CONNET, OLIVER WESTON. Civ. and Municipal Engr., 727 Reservoir St., Baltimore, Md		April 18, 1916
COOK, PAUL DARWIN. Cons. Engr., 518 United Bank Bldg., Sioux City, Iowa	Assoc. M. M.	Jan. 31, 1911 June 24, 1916

MEMBERS (*Continued*)

		Date of Membership.
COWIE, HARRY JAMES. Designing Engr., The Niagara Falls Power Co., Canadian Niagara Power Co., and Niagara Junction Ry., Niagara Falls, N. Y.	Assoc. M. M.	Feb. 28, 1911 June 24, 1916
DERICKSON, DONALD. Cons. Structural Engr.; Head of School of Civ. Eng., and Prof. of Civ. Eng., Tulane Univ., New Orleans, La.	Assoc. M. M.	Sept. 2, 1914 May 31, 1916
ELLIS, NATHAN RANDALL. Valuation Engr., City Attorney's Office, 1176 Dolores St., San Francisco, Cal.		June 23, 1916
FITZGERALD, WALTER LEWIS. Asst. Works Mgr., Edward G. Budd Mfg. Co., 222 Sydney St., Mt. Airy, Philadelphia, Pa.	Assoc. M. M.	May 3, 1910 June 24, 1916
GILLEN, FRANCIS FAIR. Supt. and Engr., Office of Public Bldgs. and Grounds, 1729 New York Ave., Washington, D. C.		May 31, 1916
GREEN, THEODORE. Vice-Pres. and Chf. Engr., Hydro Constr. Co., 1010 Mutual Life Bldg., Buffalo, N. Y.	Assoc. M. M.	Mar. 1, 1910 May 31, 1916
GROSS, DANIEL WINGERD. Valuation Engr., A. C. L. R. R., Wilmington, N. C.	Assoc. M. M.	May 1, 1901 June 24, 1916
HILES, ELMER KIRKPATRICK. Secy., Engineers' Society of Western Pennsylvania, 5537 Hampton St., Pittsburgh, Pa.		June 23, 1916
HUNTER, WALTER GLADDEN. Cons. Engr., 611 Commercial & Savings Bank Bldg., Stockton, Cal.	Assoc. M. M.	April 30, 1912 May 31, 1916
HURLBUT, CHARLES CHASE. Architectural Engr., 101 Park Ave., New York City.	Assoc. M. M.	Dec. 5, 1906 Mar. 14, 1916
JACKSON, JOSEPH FREDERICK. Eng. Member, State Board of Health, 185 Church St., New Haven, Conn.	Assoc. M. M.	Sept. 3, 1913 June 24, 1916
JACOBS, CHARLES CLEFFORD. Contr. Engr., Amboy, Ill.		Dec. 6, 1915
JENKINS, JENKS BUFFUM. Valuation Engr., B. & O. System, B. & O. Bldg., Baltimore, Md.		April 18, 1916
KLEIN, WILLIAM IGNATIUS. Res. Engr., The New York Continental Jewell Filtration Co., 313 Interstate Bldg., Kansas City, Mo.		May 31, 1916
LARMON, FRANK PERRY. Chf. Engr., Consolidated Water Co., 11 Grant St., Utica, N. Y.	Assoc. M. M.	July 9, 1906 June 24, 1916
LOTHHOLZ, HARRY CHARLES. Engr. of Design, C., M. & St. P. Ry., 1345 Ry. Exchange Bldg., Chicago, Ill.		May 31, 1916
MAGRUDER, FRANK CECIL. Engr. and Mgr., Farmers Irrig. Dist., Scottsbluff, Nebr.	Jun. Assoc. M. M.	Sept. 6, 1904 Oct. 4, 1910 April 19, 1916

MEMBERS (*Continued*)

Member	Grade	Date of Membership.
MINOR, CYRUS EDWARD. Engr. of Constr., Rawley Mine, Bonanza, Colo..........	Assoc. M. M.	May 31, 1910 June 24, 1916
NOONAN, EDWARD JOSEPH. Secy. and Prin. Engr., Chicago Ry. Terminal Comm., 175 West Jackson Boulevard, Room 559, Chicago, Ill..........................		June 23, 1916
NORTH, ARTHUR TAPPEN. Contr. Engr. (Abraham Lund Co.), 19 South La Salle St., Chicago, Ill........................	Assoc. M. M.	Feb. 7, 1906 Jan. 18, 1916
NOYES, HARRY LINCOLN. Chf. Engr., Union Carbide Co., Niagara Falls, N. Y......	Assoc. M. M.	June 5, 1901 April 19, 1916
O'HEARN, JOHN LYNCH. 725 Insurance Bldg., Oklahoma, Okla.....................	Jun. Assoc. M. M.	Feb. 5, 1907 Nov. 4, 1908 June 24, 1916
PHILLIPS, AUGUSTUS LYON. Cons. Engr., 502 Coleman Bldg., Philadelphia, Pa..........................		June 23, 1916
RAMEY, HORACE PATTON. Div. Engr., San. Dist. of Chicago, 910 South Michigan Ave., Room 700, Chicago, Ill..........	Assoc. M. M.	Oct. 3, 1911 June 24, 1916
REYNOLDS, ROBERT SPINK. First Asst. to Engr. of Structures, N. Y., N. H. & H. R. R., 85 Smith St., West Haven, Conn.................................		May 31, 1916
RICE, LINDLEY MARSHALL. Chf. Engr. and Gen. Mgr., Klickitat Irrig. & Power Co., Seattle, Wash........		May 31, 1916
ROBBINS, DANA WATKINS. Const. Engr. (Dana W. Robbins, Inc.), 376 Genesee St., Utica, N. Y....................	Assoc. M. M.	Oct. 3, 1906 June 24, 1916
SAUERMAN, HENRY BURGER. Cons. Engr., 6451 Ellis Ave., Chicago, Ill...............	Assoc. M. M.	May 1, 1907 May 31, 1916
SAYFORD, NED HENSEL. Treas., The Morgan Eng. Co., 608 Goodwyn Inst. Bldg., Memphis, Tenn....................	Assoc. M. M.	Dec. 3, 1912 June 24, 1916
SHAW, WALTER ADAM. Member, State Public Utilities Comm. of Illinois, 1509 Farwell Ave., Chicago, Ill..		May 31, 1916
STEVENS, WILLIAM WENTWORTH. Mgr., Constr. Dept., Standard Oil Co. of New York, Shanghai, China.....................	Assoc. M. M.	June 24, 1914 Mar. 14, 1916
TARR, SIMON WEINBERG. Engr. of Constr., Oliver Iron Min. Co., Wolvin Bldg., Duluth, Minn............		May 31, 1916
TOLL, ROGER WOLCOTT. Chf. Engr., The Denver Tramway Co., 790 Washington St., Denver, Colo.....................	Jun. Assoc. M. M.	Oct. 5, 1909 Nov. 12, 1913 April 19, 1916
VANCE, WILLIAM HERBERT. Engr., M. of W. La. & Ark. Ry., Stamps, Ark..............................		June 23, 1916
YOUNG, ALEXANDER RIRIE. City Engr., 1311 Clay St., Topeka, Kans...............	Assoc. M. M.	Sept. 5, 1911 April 19, 1916

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ABBOTT, WALTER RUSSELL. Constr. Engr., with Keith O. Guthrie, 2 Cornelius Ave., Schenectady, N. Y.		April 18, 1916
ACKERMAN, ARTHUR POPE. Great Barrington, Mass.	Jun. Assoc. M.	June 30, 1910 April 18, 1916
AUSTILL, HURIEOSCO. Bridge Engr., Mobile & Ohio R. R., Mobile, Ala.		Mar. 14, 1916
BALDWIN, THOMAS ABBOTT. Res. Engr., The Pennsylvania Steel Co., Box 2221, De Soto Station, Memphis, Tenn.	Jun. Assoc. M.	July 9, 1912 May 31, 1916
BATES, CLARENCE MYERS. Structural Engr., Pacific Dist., Interstate Commerce Comm., 731 Wells Fargo Bldg., San Francisco, Cal.	Jun. Assoc. M.	Feb. 4, 1913 May 31, 1916
BAVER, WALTER SAMUEL. Asst. San. Engr., City of Johnstown, 401 Association Pl., Johnstown, Pa.		April 18, 1916
BAYLIS, JOHN ROBERT. Mgr., Jackson Water Works, Jackson, Miss.		June 23, 1916
BELL, JOHN WILSON. 622 Ellis Ave., Ashland, Wis.		Dec. 6, 1915
BLASER, ARTHUR FREDERICK. 10003 Newton Ave., Cleveland, Ohio		May 31, 1916
BOGGESS, LOUIS STERLING. Dist. Engr., Bureau of Public Works, Naga, Ambos Camarines, Philippine Islands.		Mar. 14, 1916
BOLDT, JOHN. Gen. Supt., The Samuel Austin & Son Co., 1108 Swetland Bldg., Cleveland, Ohio		May 31, 1916
BOWLBY, HENRY LEE. Care, Home Telephone & Telegraph Co., Portland, Ore.		Mar. 14, 1916
BOYNTON, ROBERT HAMMOND. City Engr., Frankfort, Ind.	Jun. Assoc. M.	May 6, 1914 April 18, 1916
BROWN, FRED MELVIN. County Surv., Gallatin County; Engr. for Manhattan, Bozeman, Mont.		May 31, 1916
BUCKWALTER, HARRIS DANIEL. Asst. Engr. Public Service Comm. of Pennsylvania, Box 44, Harrisburg, Pa.		May 31, 1916
BUELL, WILLIAM ELIJAH, JR. Asst. Engr., Ambursen Hydr. Constr. Co. of Canada, Ltd., and Raymond Concrete Pile Co., 756 Sherbrooke St., West, Montreal, Que., Canada	Jun. Assoc. M.	June 24, 1914 April 18, 1916
CHANDLER, JOHN HENRY. Box 55, Bartlesville, Okla.		June 23, 1916
CHASE, EDWARD SHERMAN. Asst. Engr., New York State Dept. of Health, Albany, N. Y.		May 31, 1916
CHILDS, JAMES ALANSON. Engr., Div. of Sanitation, State Board of Health, 1988 Summit Ave., St. Paul, Minn.		April 18, 1916
CISSEL, JAMES HARLAN. Instr. in Civ. Eng., Univ. of Michigan, 1213 S. State St., Ann Arbor, Mich.		May 31, 1916

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CLEVELAND, JOHN ABELL. Chf. Engr. and Director Gen., Constr. of the Ferrocarril á la Costa, Box 197, Guayaquil, Ecuador		Mar. 14, 1916
CORLETT, WILLIAM GREENFIELD. Draftsman and Engr., Walter D. Reed, Oakland Bank of Savings Bldg., Oakland, Cal.	Jun. Assoc. M.	Dec. 2, 1914 May 31, 1916
COTTRELL, FREDERICK WILLIAM. Engr., Melville Irrig. Co., Deseret Irrig. Co., and Sevier Land & Water Co., Delta, Utah		May 31, 1916
CROOKES, HAROLD JOSEPH. 2 West 16th St., New York City.		May 31, 1916
DIMMLER, CHARLES LOUIS. Structural Engr., Div. of Valuation, Interstate Commerce Comm., 1330 Josephine St., Berkeley, Cal	Jun. Assoc. M.	Oct. 1, 1907 April 18, 1916
DODGE, FRANK EARLE. Supt. of Maintenance, New York & New England Cement & Lime Co., 502 Clinton St., Hudson, N. Y.	Jun. Assoc. M.	Feb. 4, 1913 June 23, 1916
ELTINGE, ORVILLE LAMONT. Asst. Engr., E. B. Murray & Co., Kansas City, Mo	Jun. Assoc. M.	Jan. 3, 1907 May 31, 1916
FAIDLEY, LLOYD HARRISON. 4812 Hammett Pl., St. Louis, Mo	Jun. Assoc. M.	Dec. 5, 1911 May 31, 1916
FAWCETT, LUTHER THOMAS. First Asst. City Engr., 365 Carroll St., Youngstown, Ohio		June 23, 1916
FORSTER, ALEXANDER SYLVESTER. Chf. Draftsman, Toledo Bridge & Crane Co., 2603 Franklin Ave., Toledo, Ohio		May 31, 1916
FOSTER, WALTER LINDER. Care, Kennecott Copper Corporation, Latouche, Alaska		May 31, 1916
FOX, WILLIAM FREDERICK. Asst. to Rd. Engr., I. R. T. Co., M. of W. Dept., 32 Walnut Ave., Rockville Center, N. Y	Jun. Assoc. M.	April 5, 1910 April 18, 1916
FRASER, LEE. (South American Eng. Corporation), 52 William St., New York City		April 18, 1916
FRAZIER, FORREST FAYE. Asst. Prof. of Civ. Eng., Kansas State Agricultural Coll., Manhattan, Kans		May 31, 1916
FRICK, ORLANDO HENRY. 686 Murray Ave., Milwaukee, Wis.		Jan. 17, 1916
FRIEDMAN, HARRY BAYARD. Supt., W. E. Wood Co., Chevrolet Motor Co. Plant, Fort Worth, Tex		Mar. 14, 1916
FROST, EDWARD MURRAY. 7 Elbridge St., Worcester, Mass	Jun. Assoc. M.	June 24, 1914 June 23, 1916
GILLIS, RIDGWAY MILLS. Asst. Engr., State Highway Dept., Kalama, Wash		April 18, 1916
GOODMAN, FRANK RAYMOND. Div. Engr., State Highway Dept., Parks, Ariz		June 23, 1916

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
GRAY, HAROLD FARNSWORTH. City Health Officer, 208 Ramona Bldg., Palo Alto, Cal	Jun. Assoc. M.	Jan. 4, 1910 Mar. 14, 1916
GUINOTTE, JOHN. Asst. Engr., M. of W., C., M. & St. P. Ry., Milwaukee Freight House, Seattle, Wash		June 23, 1916
HALLETT, JAMES HENDRICKS. Chf. Clerk, Jacksonville Eng. Dept., Jacksonville, Fla		June 23, 1916
HARDESTY, SHORTRIDGE. Asst. Engr., Waddell & Son, 800 Graphic Arts Bldg., Kansas City, Mo	Jun. Assoc. M.	Sept. 1, 1908 Mar. 14, 1916
HASKINS, CHARLES ARTHUR. Engr., Kansas State Board of Health, Lawrence, Kans		June 23, 1916
HEERLEIN, ROBERT WILLIAM. Asst. Engr., Estimating and Designing Dept., McClintic-Marshall Co., P. O. Box 418, Pittsburgh, Pa		May 31, 1916
HEILBRONNER, LEON COHEN. Engr. and Mgr., Eastover Constr. Co., Inc., Box 242, Utica, N. Y	Jun. Assoc. M.	Mar. 2, 1909 May 31, 1916
HERZIG, SOLON. 472 West End Ave., New York City	Jun. Assoc. M.	Oct. 1, 1913 June 23, 1916
HEWETT, FREEMAN REGINALD. Constr. Engr. of Adams County; City Engr., Ritzville, Wash		June 23, 1916
HIESIGER, CHARLES MILTON. Examining Insp. in Office, Commr. of Accounts; Consultant with Phœnix Eng. Co., 5 Beekman St., New York City		June 23, 1916
HINGSBURG, FREDERICK CHARLES. Care, Mr. Lyons, Box 36, Kingston, Jamaica		May 31, 1916
HIRAI, KIKUMATSU. Care, Yamanaka & Co., 254 Fifth Ave., New York City	Jun. Assoc. M.	Dec. 5, 1911 May 31, 1916
HOCHENEDEL, CHARLES ANTHONY. City Civ. Engr., Fremont, Ohio		May 31, 1916
HORTON, CHARLES KAAPKE. Gen. Contr. (Horton & Horton), Houston, Tex		June 23, 1916
HOWLAND, LEON DAVID. County Engr., Union County, La Grande, Ore	Jun. Assoc. M.	Feb. 4, 1914 May 31, 1916
HUIE, IRVING VAN ARNAM. Asst. Engr., F. A. Molitor, 223 East 31st St., New York City	Jun. Assoc. M.	May 7, 1913 May 31, 1916
HUNTER, HARRY GRIFFITH. 1024 North Liberty St., Independence, Mo		May 31, 1916
HUTTON, MURRAY LEE. County Engr., Des Moines County, Court House, Burlington, Iowa		June 23, 1916
IAKISCH, JOHN RUDOLPH. Constr. Engr. on Drainage, U. S. Reclamation Service, Powell, Wyo		April 18, 1916

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
IBARGÜEN Y PI, ALBERTO ANGEL. Provisional Chf. Engr. of Public Works, District of Pinar del Rio, Marti 47, Pinar del Rio, Cuba		June 23, 1916
IBARRA CEREZO, JOSÉ MARIA. Director of Dept. of Ways and Communications, Ministry of Public Works, Sur 5, No. 157, Caracas, Venezuela		June 23, 1916
JESSOP, GEORGE AUGUSTUS. Care, S. Morgan Smith Co., York, Pa		May 31, 1916
KAESTNER, ALBERT CARL. Asst. to Chf. Engr., U. S. Realty & Impvt. Co., 949 Broadway, Room 702 (Res., 2216 Starling Ave.), New York City	Jun. Assoc. M.	Jan. 2, 1912 May 31, 1916
KELLY, HUGH AMBROSE. Engr., Dept. of Parks and Public Property; City Plan Engr., 33 Baldwin Ave., Jersey City, N. J	Jun. Assoc. M.	Oct. 29, 1912 May 31, 1916
KRAUSE, MARK CHAMPION. 335 Pine St., Williamsport, Pa.		May 31, 1916
LANDER, ROSWELL SEARS. Associate Engr. with Soper Eng. Co., Winchester, Tenn		Jan. 17, 1916
LANGLEY, JOHN EDWARD. Supt. of Constr., Treasury Dept., Southport, N. C		Mar. 14, 1916
LEE, ALONZO CHURCH. Care, Knight & Quayle, 408 Times Bldg., Chattanooga, Tenn		June 23, 1916
LEHFELT, WALT FERD. Care, International Boundary Comm., Malvina, Que., Canada		April 18, 1916
LILLY, RIDGELY CASEY. U. S. Junior Engr., Box 404, Vicksburg, Miss	Jun. Assoc. M.	Oct. 5, 1909 April 18, 1916
LUTHER, HERBERT LAWRENCE. Care, Missouri Val. Bridge & Iron Co., Boise, Idaho		May 31, 1916
MCENTIRE, LLOYD. Div. Highway Engr., State Rd. Dept., 224 North Warren St., Trenton, N. J	Jun. Assoc. M.	Sept. 2, 1914 May 31, 1916
MANLEY, HENRY, JR. Asst. Engr., Public Service Comm., 1594 Hayes Ave., Elmhurst, N. Y		May 31, 1916
MEISTER, FREDERICK. Chf. Draftsman and Designing Engr., The Hinkle Iron Co., 309 High St., West Hoboken, N. J		June 23, 1916
MILLER, HAROLD BROWN. Asst. Engr., Designing and Estimating Depts., McClintic-Marshall Co., 1217 Oliver Bldg., Pittsburgh, Pa		June 23, 1916
MILLER, HAROLD EDMUND. 29 Elma St., Providence, R. I	Jun. Assoc. M.	Oct. 1, 1907 May 31, 1916
MILLER, WILLIAM FRANKLIN. Superv., Office of Valuation Engr., P. R. R., Commercial Trust Bldg., Philadelphia, Pa		May 31, 1916
MOLLARD, CHARLES ELIAS. Cons. Engr., Park Ridge, Ill		May 31, 1916

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
NORTH, ROBERT GASTON. 60 Springside Ave., Pittsfield, Mass.		Dec. 6, 1915
PANZER, ROBERT RUDOLPH. Chf. Engr., Dept. of Bldgs., 515 Hawthorne Ave., Cincinnati, Ohio		May 31, 1916
PARSONS, HAROLD FRANK. Res. Engr., George W. Fuller, Thomson Bldg., Huntington, N. Y.		May 31, 1916
PAULS, ARTHUR LEONARD. Irrig. Engr., Gen. Land Office, Box 336, Cheyenne, Wyo.		May 31, 1916
PEARCE, HARRY ASH. Engr. and Contr. (Pearce & Sexton), Ancon, Canal Zone, Panama		April 18, 1916
PIRNIE, HERBERT MALCOLM. 112 Magnolia Terrace, Springfield, Mass.	Jun. Assoc. M.	Feb. 4, 1914 June 23, 1916
PURTON, ASTLEY BLOXAM. Asst. Engr., U. S. Geological Survey, 421 Federal Bldg., Salt Lake City, Utah		May 31, 1916
RANKIN, CARL ROY. Locating Engr. for City and County of San Francisco Hetch Hetchy Water Supply, Groveland, Cal.		June 23, 1916
RASMUSSEN, BERNHARD. Asst. Engr., Santo Domingo Obras Publicas, La Vega, Santo Domingo, Dominican Republic		April 18, 1916
RINDSFOOS, CHARLES SIESEL. Pres., U. S. Purchasing Corporation, Room 1689, Woolworth Bldg., New York City	Jun. Assoc. M.	April 2, 1907 May 31, 1916
ROBERTS, BURKE BROCKWAY. Asst. Engr., James L. Stuart, 917 Illuminating Bldg., Cleveland, Ohio	Jun. Assoc. M.	Dec. 2, 1914 May 31, 1916
ROBY, HARRISON GEORGE. Gen. Mgr., City of Alpena, National Bank Bldg., Alpena, Mich.		May 31, 1916
ROHR, WILKIE CLAIBORNE. Engr., T. C. Thompson & Bros., Box 97, Charlotte, N. C.		May 31, 1916
ROUSE, HERBERT MILTON. Supt., Val. Div., California Development Co., Calexico, Cal.		May 31, 1916
RUMSEY, WILLIAM MILO. Room 529, Granger Blk., San Diego, Cal.		Nov. 3, 1915
SANDSTON, LEONARD MARK. 17 Gramercy Park, New York City		May 31, 1916
SANDSTROM, ARTHUR CHARLES. Care, Constr. Dept., Braden Copper Co., Rancagua, Chili, *via* Colon and Valparaiso		May 31, 1916
SCHOLTZ, HERMAN FRED. Care, Moses, Pope & Messer, Inc., 366 Fifth Ave., New York City	Jun. Assoc. M.	Oct. 30, 1906 April 18, 1916
SMITH, EVERETT CLERC, JR. Point Pleasant, W. Va.		April 18, 1916
SMITH, GEORGE WASHINGTON. 1828 Lytton Bldg., Chicago, Ill.	Jun. Assoc. M.	Jan. 31, 1911 June 3, 1915

ASSOCIATE MEMBERS (*Continued*)		Date of Membership.
SMITH, SCHUYLER MORTON. In Chg., Bridge Dept. Drafting Room, Wabash Ry., 1467 Ry. Exchange Bldg., St. Louis, Mo		May 31, 1916
SORTORE, ARTHUR EMERSON. Asst. Engr., Div. of Bridges, Bureau of Eng., Benton Ave. and Atkins St., Pittsburgh, Pa		May 31, 1916
SPENGLER, JOHN HENRY. With Westinghouse, Church, Kerr & Co., 37 Wall St., New York City	Jun. Assoc. M.	June 6, 1911 May 31, 1916
STARK, BURR MANLOW. 30th and Spruce Sts., Philadelphia, Pa		May 31, 1916
STOWE, HENRY DANIELS. Pilot Engr., Valuation Dept., P. R. R., 534 Commercial Trust Bldg., Philadelphia, Pa		June 23, 1916
SWETT, WILLIAM CLAUDE. 3602 Windsor Ave., Kansas City, Mo	Jun. Assoc. M.	Nov. 1, 1910 Mar. 14, 1916
TAIT, WILLIAM STUART. Chf. Engr., Concrete Steel Products Co., 855 McCormick Bldg., Chicago, Ill		May 31, 1916
THOMSEN, SAMUEL LOCKE. Res. Engr. and Supt., The E. H. Close Realty Co., 2860 Scottwood Ave., Toledo, Ohio.		May 31, 1916
THORPE, JOHN EDWARD STIRLING. Res. Engr., Aluminum Co. of America, Care, Talassee Power Co., Whitney, N. C		May 31, 1916
TOMLINSON, WILLIAM SIDNEY. Engr., Shand Eng. Co., 1002 Loan and Exchange Bldg., Columbia, S. C	Jun. Assoc. M.	Sept. 3, 1912 Dec. 6, 1915
TRACY, HERBERT HERMAN. City Engr., Norfolk, Nebr		April 18, 1916
TRUSCOTT, STARR. Birmingham, Ohio		May 31, 1916
TURNER, HOMER ROOT. Supt., Windsor Fire Dist., Windsor, Conn		Mar. 14, 1916
UPSON, WARREN WILLIAM. Bldg. Contr. (Wise & Upson), 36 Pearl St., Hartford, Conn		May 31, 1916
VOGEL, ANDREW. Prin. Asst., R. D. Bradbury, 68 Devonshire St., Boston, Mass		May 31, 1916
WADSWORTH, LEWIS LUMBER. Pres. and Cons. Engr., Hanscom Constr. Co., 70 Kilby St., Boston, Mass		June 3, 1915
WALL, EDWARD WALTER. Gen. Supt., The Atlas Constr. Co., 37 Belmont St., Montreal, Que., Canada	Jun. Assoc. M.	Dec. 6, 1910 Mar. 14, 1916
WAUGH, ERNEST JUDSON. Engr., Hydro-Elec. Co., Pacific Power Co., Pacific Power Corporation, and Hillside Water Co., Benton, Cal		May 31, 1916
WERTHEIMER, MAX. Asst. to Bridge Engr., Cuyahoga County, 7216 Lorain Ave., Cleveland, Ohio		May 31, 1916

ASSOCIATE MEMBERS (*Continued*) — Date of Membership.

WHITLOW, FRANK WALLACE. Supt. of Constr., Milwaukee County Highway Dept., 518 Grove St., Milwaukee, Wis.		May 31, 1916
WILEY, RALPH BENJAMIN. Asst. Prof., Hydr. and San. Eng., Purdue Univ., 1012 Seventh St., West Lafayette, Ind.	Jun. Assoc. M.	Feb. 4, 1908 May 31, 1916
WOLPERT, OTTO. Prin. Asst. Engr., Butterworth & Judson Corporation, 61 Broadway, New York City		June 23, 1916
WONDRIES, CHARLES HENRY. Res. Engr., California Highway Comm., El Centro, Cal.		Mar. 14, 1916
WOODRUFF, GLENN BARTON. Bridge Designer, L. V. R. R., Care, Bridge Dept., L. V. R. R., South Bethlehem, Pa.	Jun. Assoc. M.	Dec. 3, 1913 June 23, 1916

JUNIORS

ATKINSON, GUY. Care, The Emerson Co., 30 Church St., New York City	June 23, 1916
BERDEAU, RAY WILLIAM. Room 103, Founders Hall, Cornell Univ., Ithaca, N. Y.	May 31, 1916
BISHOP, ROY PRENTICE. Brooklyn, Iowa	June 23, 1916
BUTLER, ARTHUR GRAY. 160 Pennsylvania Ave., Louisville, Ky.	June 23, 1916
DAVIS, FREDERICK AUGUSTUS WILLIAM. Eng. Dept., The Amco Glazed Block Co., 347 Fifth Ave., New York City	April 18, 1916
DE LA GUARDIA, GUILLERMO. Care, Chas. E. Griffin, 24 Stone St., New York City	April 18, 1916
DOW, HEZEKIAH SHAILER. 604 West 115th St., New York City	April 18, 1916
FERGUSON, HARRY FOSTER. Prin. Asst. Engr., Illinois State Water Survey, Urbana, Ill.	June 23, 1916
FITZGERALD, WILLIAM EDWARD. 113 Radcliffe St., Bristol, Pa.	May 31, 1916
GREACEN, JOHN LYLE. 384 Fourth St., Brooklyn, N. Y.	June 23, 1916
GROSS, FREDERICK HENRY. Eng. Dept., Bronx Parkway Comm., 17 William St., White Plains, N. Y.	May 31, 1916
HEFFELFINGER, JOHN MILTON, JR. Asst. Res. Engr., Columbus Sewage Treatment Improvement, 32 East Innis Ave., Columbus, Ohio	June 23, 1916
HESLOP, PAUL LOVERIDGE. 401 Boyd Ave., Memphis, Tenn.	June 23, 1916
JONES, HARRY EDWARD. Transitman, M. of W. Dept., Lehigh Val. R. R., 236 Jersey St., Buffalo, N. Y.	June 23, 1916
LYTLE, HENDRIX GILBERT. Care, Div. Engr., T. & P. Ry., Marshall, Tex.	June 23, 1916
MEANS, JOHN SIEMON. 1563 Downig St., Denver, Colo.	April 18, 1916

JUNIORS (*Continued*)	Date of Membership.
NAGLER, FLOYD AUGUST. 1317 Washtenaw Ave., Ann Arbor, Mich	Mar. 14, 1916
OATMAN, FRANKLYN WILLIAM. 1319 Leavenworth St., San Francisco, Cal	Mar. 14, 1916
O'DONNELL, JOHN ROBERT. 394 East 16th St., Brooklyn, N. Y	May 31, 1916
PUNG, WILLIAM SING-CHONG. Rodman, Oil Fields and and Santa Fe Ry., P. O. Box 248, Cushing, Okla	May 31, 1916
RICHMOND, ALLEN PIERCE. Care, Central Aguirre Co., Central Aguirre, Porto Rico	June 23, 1916
SLEIGHT, REUBEN BENJAMIN. Asst. Irrig. Engr., Office of Experiment Stations, U. S. Dept. of Agriculture, 301 Tramway Bldg., Denver, Colo	Dec. 6, 1915
SOMMER, ISADORE MENDELSOHN. Designing Engr., Edward L. Soulé Co., 2852 California St., Apartment 6, San Francisco, Cal	May 31, 1916
STANLEY, WILLIAM EDWARD. 3210 Artlington St., Chicago, Ill	May 31, 1916
STAUFFER, ISAAC YOST. Care, Standard Oil Co. of New York, Batavia, Java	May 31, 1916
STRUTHERS, DAVID LINDSAY. City Engr., Wilmington, N. C.	Mar. 14, 1916
TEMPLIN, RICHARD LAURENCE. 3912 Campbell St., Kansas City, Mo	April 18, 1916
TONG, YUNG TSO. Care, Tong Hon Sing, Chinese Post Office, Tientsin, China	Mar. 14, 1916
VON DEESTEN, ARTHUR PETER. First Lieut., Corps of Engrs., U. S. A.; Engr., Field Depot, Columbus, N. Mex	June 23, 1916
WAITE, CLEMENT F. Draftsman, Skamania County Highways, Underwood, Wash	May 31, 1916
WEBB, CLAUDE ALLEN. 4432 Tracy St., Kansas City, Mo	April 18, 1916
YOUNGLING, LOUIS SHEMALD. 453 West 34th St., New York City	May 31, 1916

CHANGES OF ADDRESS

MEMBERS

ABBOTT, FRED WALTER. 6718 Quincy St., Mt. Airy, Philadelphia, Pa.

ABBOTT, HUNLEY. Vice-Pres. and Chf. Engr., MacArthur Concrete Pile & Foundation Co., 120 Broadway, New York City.

BALDWIN, ERNEST HOWARD. Asst. Chf. of Constr., U. S. Reclamation Service, El Paso, Tex.

BAYLIS, ARTHUR RAYMOND. Asst. Engr. on Constr., I. R. T. Co. and New York Rys., 600 West 59th St., New York City.

MEMBERS (*Continued*)

BENT, CORNELIUS CONWAY FELTON. 1206 Widener Bldg., Philadelphia, Pa.

BILLIN, CHARLES EMERY. Southbury, Conn.

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BREWSTER, HENRY BAUM. Engr., H. S. Kerbaugh, Inc., Box 383, Rochester, N. Y.

BRYSON, ANDREW. New Castle, Del.

BURGESS, HARRY. Maj., Corps of Engrs., U. S. A., Room 337, Federal Bldg., Detroit, Mich.

BUTTS, EDWARD PONTANY. 60 Mulberry St., Springfield, Mass.

CANTINE, EDWARD IKE. Chf. Deputy State Engr., Room 303, State House, Salem, Ore.

CARLSON, CARL ALEXIUS. Civ. Engr., U. S. N., Navy Yard, Mare Island, Cal.

CARPENTER, CHARLES LINCOLN. 26 Morton St., Andover, Mass.

CHARLES, LA VERN JOHN. 566 High St., Denver, Colo.

CLAPP, OTIS FRANCIS. (*Director.*) 11 Bridgham St., Providence, R. I.

COCHRANE, VICTOR HUGO. Engr. of Bridges, City Hall, Kansas City, Mo.

COE, DAVID. Hengoed, *via* Cardiff, England.

COLLIER, BRYAN CHEVES. Constr., Engr., Traylor Eng. & Mfg. Co. (Res., 125 North 17th St.), Allentown, Pa.

COLPITTS, WALTER WILLIAM. (Coverdale & Colpitts), 66 Broadway, New York City.

CONNOR, WILLIAM DURWARD. Maj., Corps of Engrs., U. S. A.; Asst. Chf. of Staff, Southern Dept., San Antonio, Tex.

CONOVER, CHARLES E. Designing Engr., Public Service Comm., 120 Broadway, New York City.

COOMBS, STEPHEN ELBRIDGE. Special Engr., N. Y. C. R. R., Room 5041, Grand Central Terminal, New York City.

CORNELL, GEORGE BIRDSALL. Cons. Engr., 94 Saratoga Ave., Yonkers, N. Y.

COURTNEY, REGINALD SYDNEY. 702 Flatiron Bldg., New York City.

COVERDALE, WILLIAM HUGH. (Coverdale & Colpitts), 66 Broadway, New York City.

CREHORE, WILLIAM WILLIAMS. Cons. Engr., Beaumont, Cal.

MEMBERS (*Continued*)

CRUMP, RALPH LEE. Merchantville, N. J.

CURTIS, LOREN BRADLEY. Benton, Cal.

CURTIS, WALTER WHALEY. Pres., The Rapson Coal Min. Co. and The Curtis Coal Co., 2006 North Cascade Ave., Colorado Springs, Colo.

CUSHMAN, WILLIAM HERBERT. Chf. Engr., Hydr. Constr. Co., Flower Bldg., Watertown, N. Y.

DARLING, FRED STEERE. 135 Friend St., Amesbury, Mass.

DART, JUSTUS VINTON. Thompson, Conn.

DONOVAN, CORNELIUS. Prin. Asst. Engr., U. S. Engr. Office, 1809 Napoleon Ave., New Orleans, La.

DOSE, HENRY FREDERICK. Dist. Engr., Alaskan Eng. Comm., Anchorage, Alaska.

ECKLES, HARRY EDWARD. 2331 West Monroe St., Chicago, Ill.

ESTEP, JOSIAH MADISON. Cons. Engr., 601 Marshall Bldg., Cleveland, Ohio.

FELLOWS, ABRAHAM LINCOLN. (The Field, Fellows & Hinderlider Eng. Co.), 946 Equitable Bldg., Denver, Colo.

FELTHAM, PERCY MARSHALL. Waycross, Ga.

FIELD, JOHN ELLIS. (Field, Fellows & Hinderlider Eng. Co.), 946 Equitable Bldg., Denver, Colo.

FOX, JOHN ANGELL. Secy.-Mgr., Mississippi River Levee Assoc., 734 Woodward Bldg., Washington, D. C.

FRANCIS, WALTER JOSEPH. Cons. Engr. (Walter J. Francis & Co.), 260 St. James St., Montreal, Que., Canada.

GAYLER, ERNEST ROTTECK. Civ. Engr., U. S. N., Care, Bureau of Yards and Docks, Navy Dept., Washington, D. C.

GILLESPIE, RICHARD HENWOOD. Chf. Engr., Sewers and Highways, Bronx, 177th St. and Third Ave. (Res., 286 East 201st St.), New York City.

GORDON, FRED FORCE. Civ. Engr., Eastman Kodak Co., 75 South Union St., Rochester, N. Y.

GORE, ELBERT BRUTUS. Capitol Bldg., Austin, Tex.

GUTMAN, DAVID. Chf. Engr., John G. Brown, Witherspoon Bldg., Philadelphia, Pa.

HAINES, HENRY STEVENS. Lenox, Mass.

HARRIS, VAN ALEN. Pocono Lake Reserve, Pocono, Pa.

HARWOOD, GEORGE ALEC. (*Director.*) Eng. Asst. to Vice-Pres. of Operation, N. Y. C. R. R., Grand Central Terminal, New York City.

HASSKARL, JOSEPH FREDERICK. Cons. Engr. (Res., 1934 North Broad St.), Philadelphia, Pa.

HAWLEY, RALPH STEVENSON. City Engr., Town Hall, Emeryville, Cal.

HAWXHURST, ROBERT, JR. Gen. Supt., Eden Min. Co., Bluefields, Nicaragua (*via* New Orleans, La.).

HIDINGER, LEROY LEMAYNE. Vice-Pres., The Morgan Eng. Cos., 610 Goodwyn Inst. Bldg., Memphis, Tenn.

HINDERLIDER, MICHAEL CREED. (Field, Fellows & Hinderlider Eng. Co.), 946 Equitable Bldg., Denver, Colo.

MEMBERS (*Continued*)

HOMBERGER, HEINRICH. Cons. Engr., Mill Valley, Cal.

HOWE, MALVERD ABIJAH. The Hermitage, Northfield, Vt.

HOWELL, GEORGE PIERCE. Lt.-Col., Corps of Engrs., U. S. A., War Dept., Washington, D. C.

HOWIE, HOWARD BENSON WILBERFORCE. Care, Canadian Copper Co., Copper Cliff, Ont., Canada.

HYDE, HOWARD ELMER. Care, Young & Hyde, Produce Exchange Bldg., New York City.

JENKINS, JAMES EDGAR. Supt., John W. Cowper Co., 725 Fidelity Bldg., Buffalo, N. Y. (Res., 644 Riverside Drive, New York City).

JONES, ARTHUR LEWIS. 300 South Olive St., Los Angeles, Cal.

KELLER, CHARLES LINCOLN. Pres., The Scherzer Rolling Lift Bridge Co., 1616 Monadnock Blk., Chicago, Ill.

KENDRICK, JOHN WILLIAM. 1733 Lytton Bldg., Chicago, Ill.

KETCHUM, RICHARD BIRD. Assoc. Prof. of Civ. Eng, Univ. of Utah (Res., 172 N St.), Salt Lake City, Utah.

KING, PAUL SORIN. Cons. Engr., 807 West Ninth St., Wilmington, Del.

KINNEAR, WILSON SHERMAN. Pres., U. S. Realty & Impvt. Co., 949 Broadway, New York City.

KNIGHT, HERBERT MILLER. 166 Camp St., Providence, R. I.

KOON, RAY EMERSON. Hydr. and San. Engr., 1506 Colby Ave., Everett, Wash.

LAIRD, HARRY SNEDDEN. Chf. Engr., Harrisville-South. R. R., The Colonial Hotel, Sharon, Pa.

LAMB, RICHARD. Cons. and Const. Engr., 90 West St., New York City.

LANGTHORN, JACOB STINMAN. Deputy Commr., Dept. of Water Supply, Gas and Electricity, Borough of Brooklyn, 50 Court St., Brooklyn, N. Y.

LATHROP, JAY COWDEN. Contr. Engr., Route 7, North Columbus, Ohio.

LEHMAN, GEORGE MUSTIN. Chf. Engr., Lake Erie and Ohio River Canal Board, 1002 Hartje Bldg., Pittsburgh, Pa.

MACALLUM, ANDREW FULLERTON. Commr. of Works, City Hall, Ottawa, Ont., Canada.

MCDANIEL, ALLEN BOYER. Gen. Eng. Bldg., Union Coll., Schenectady, N. Y.

MCDONOUGH, CHARLES JOSEPH. Div. Engr., State Highway Dept. (Res., 81 Crescent Ave.), Buffalo, N. Y.

MCINNES, FRANK ALEXANDER. 23 Salcombe St., Dorchester, Mass.

MCINTYRE, WILLIAM AINSWORTH. Asst. Mgr., Hyrib, Lath and Highway Dept., Trussed Concrete Steel Co., Youngstown, Ohio.

MCKAY, GEORGE ALBERT. Civ. Engr., U. S. N.; Public Works Officer, Bureau of Yards and Docks, Navy Dept., Washington, D. C.

MCREYNOLDS, ORVAL OMAR. Chf. Engr., and Gen. Mgr., San Joaquin Val. Farm Lands Co., 318 H. W. Hellman Bldg., Los Angeles, Cal.

MANAHAN, ELMER GOVE. Res. Engr., Board of Water Commrs., Wilmington, Del.

MEMBERS (*Continued*)

MARANI, VIRGIL GEORGE. Cons. Engr., 205 West Monroe St., Chicago, Ill.

MATHEWSON, THOMAS KNIGHT. Care, L. H. Long, Southern Pacific of Mexico Ry., Tucson, Ariz.

MILLARD, CHARLES STERLING. Supt., C., C., C. & St. L. Ry., Mattoon, Ill.

MILLIS, JOHN. Col., Corps of Engrs., U. S. A., U. S. Engr. Office, P. O. Bldg., Savannah, Ga.

MOLITOR, DAVID ALBERT. Cons. Engr., 319 Bewick Ave., Detroit, Mich.

MONCRIEFF, ALEXANDER BAIN. 6 College St., St. Peters, Adelaide, South Australia.

MORGAN, ARTHUR ERNEST. Pres., Dayton Morgan Eng. Co., City National Bank Bldg., Dayton, Ohio.

MORRISON, HARRY JOHNSON. Mullens, W. Va.

MORSE, HOWARD SCOTT. Engr., Detroit Bureau of Governmental Research, 100 Griswold St., Detroit, Mich.

MORSE, WALTER LEVI. Special Asst. Engr., N. Y. C. R. R., Grand Central Terminal, New York City.

MOWER, HARRISON CURTIS. U. S. Asst. Engr., U. S. Engr. Office, P. O. Box 976, Mobile, Ala.

OAKES, JOHN CALVIN. Maj., Corps of Engrs., U. S. A., 815 Witherspoon Bldg., Philadelphia, Pa.

PAGE, WILLIAM NELSON. Pres., The Gauley Mountain Coal Co., Ansted, W. Va.

PARDEE, JAMES THOMAS. Cons. Engr., P. O. Box 226, Midland, Mich.

PEASE, FLOYD ODELL. Sanmaur, *via* La Tuque, Que., Canada.

PERKINS, CHARLES PENROSE. Rosemont, Pa.

PETTEE, EUGENE EVERETT. Care, J. R. Worcester & Co., 79 Milk St., Boston, Mass.

PEW, ARTHUR. Cons. Engr., 500 Forsyth Bldg., Atlanta, Ga.

PHIPPS, THOMAS ELMER. Chf. Engr., Public Service Comm. of Washington, Olympia, Wash.

POLLEYS, WILLIAM VAUGHAN. Buttonwoods, R. I.

POND, HENRY OTIS. Managing Engr., E. B. Cadwell & Co., Inc., 25 Broad St., New York City.

POWELSON, WILFRID VAN NEST. Cons. Engr., 61 Broadway, New York City.

RANDLE, GEORGE NELSON. Engr., Reclamation Dist. No. 1500, California Fruit Bldg., Sacramento, Cal.

RASTER, WALTHER. 6743 Greenview Ave., Chicago, Ill.

REAL Y GAILLARD, JUAN D. Ferro Carril de Cuba, Camaguey, Cuba.

REYNDERS, JOHN VAN WICHEREN. Vice-Pres., The Pennsylvania Steel Co., 120 Broadway, Room 2218, New York City.

RIPLEY, BLAIR. Lt.-Col., O. C. First Constr. Battalion, 6 Nanton Court, Nanton Ave., Toronto, Ont., Canada.

ROBERTSON, DAVID. Gen. Delivery, Norfolk, Va.

ROHRER, GRANT. Contr., 280 Madison Ave., New York City.

ROUSSEAU, HARRY HARWOOD. Rear-Admiral, U. S. N., 257 Broadway, Troy, N. Y.

MEMBERS (*Continued*)

SAVAGE, HIRAM NEWTON. 2820 Park Ave., San Diego, Cal.

SCHILDHAUER, EDWARD. Pres., Artillery Fuse Co., P. O. Box 516, Wilmington, Del.

SHAW, SUMNER FARNHAM. Apartado 38, Guatemala, Guatemala.

SHOEMAKER, HARRY IVES. Engr., Welch, Fairchild & Co., Inc., San José, Mindoro, Philippine Islands.

SIDENIUS, HARRY. Lieut., Care, Gen. Staff Officer, Sarcee Military Camp, Calgary, Alberta, Canada.

SIKES, ZENAS HARRISON. Asst. Engr. of Structures, N. Y. C. R. R. Lines East of Buffalo, Exterior Zone, Grand Central Terminal, New York City (Res., 343 Hawthorne Ave., Yonkers, N. Y.).

SINKS, FRANK FORREST. Engr. and Sales Mgr., Pacific Coast Steel Co., 915 Alaska Bldg., Seattle, Wash.

STERN, ISAAC FARBER. Cons. Engr., 1390 Old Colony Bldg., Chicago, Ill.

TAYLOR, HARRY. Col., Corps of Engrs., U. S. A., 39 Whitehall St., New York City.

THIAN, PROSPER EUGENE. Valuation Engr., N. P. Ry., 1200 N. Pac. Ry. Bldg., St. Paul, Minn.

TÖNNESEN, TOBIAS. Striberg, Sweden.

TORRANCE, WILLIAM MARTIN. Cons. Engr.; Vice-Pres., and Chf. Engr., Carson Cons. Co., 123 Bull St., Savannah, Ga.

TROUT, HARRY EDGAR. 14th and High Sts., Louisville, Ky.

TUTHILL, JOB. Crown Bldg., Cleveland, Ohio.

VAN HOESEN, EDMUND FRENCH. 1517 Fairfax Ave., Hollywood, Cal.

VINCENT, EDWARD FRANKLIN. Chf. Engr., Colo. & South. Ry., 459 Ry Exchange Bldg., Denver, Colo.

VINCENT, EDWIN DERICKSON. 1960 Vista Del Mar Ave., Hollywood, Cal.

VON PHUL, WILLIAM. (Ford, Bacon & Davis), 1991 Broadway St., San Francisco, Cal.

WALTER, RAYMOND F. Asst. Chf. of Constr., U. S. Reclamation Service, Denver, Colo.

WARNER, EDWIN HALL. 2326 West 23d St., Los Angeles, Cal.

WEATHERLY, EVERETT PINE. 216 Dwight Bldg., Kansas City, Mo.

WEYMOUTH, FRANK ELWIN. Chf. of Constr., U. S. Reclamation Service, Denver, Colo.

WHITMAN, EZRA BAILEY. Engr. (Norton, Bird & Whitman), 1320 Munsey Bldg., Baltimore, Md.

WRIGHT, JOSEPH. Engr., U. S. Reclamation Service, 924 Fifth Ave., North, Great Falls, Mont.

YOUNG, HENRY AMERMAN. Treas. and Mgr., Young & Hyde, Inc., Produce Exchange Bldg., New York City (Res., 10 Myrtle Ave., Maplewood, N. J.).

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ALDEN, LANGFORD TAYLOR. Little Compton, R. I.

ALLISON, JOSEPH CHESTER. Anderson Bldg., Calexico, Cal.

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KAUFMANN, ERNST GUSTAV. 735 Delaware Ave., Buffalo, N. Y.

KRACH, FRED ROY. Insp., Inland Steel Co., 6340 Sangamon St., Chicago, Ill.

LEONARD, EDWARD PHILIP. 1115 Carroll St., Brooklyn, N. Y.

LEWIS, HAROLD MACLEAN. Asst. Engr., Charles W. Leavitt, 220 Broadway, New York City (Res., Loretto, Pa.).

MAGOR, STUART FABIAN. Supt., Brashear-Burns Co., 427 I. N. Van Nuys Bldg., Los Angeles, Cal.

MORSE, FREDERICK THURLOUGH. Care, Chf. Engr. of Santa Fé Ry., Topeka, Kans.

NELSON, ERNEST BENJAMIN. Care. Andes Exploration Co., Chañaral, Chili.

NOLAN, QUINCES ROBERTUS. Res. Engr. with Hillside Cotton Mills, La Grange, Ga.

OGDEN, MERTON MILES. Transitman, Div. of Surveys, Panama Canal, Balboa Heights, Canal Zone, Panama.

ORT, ALBERT AUGUST LAMBERT. Asst. Engr., Miami Conservancy Dist., Dayton, Ohio.

PATTERSON, CHARLES SCOTT. Div. Engr., M., K. & T. Lines, P. O. Box 21, Wichita Falls, Tex.

PAYNE, LOUIS WATTERS. Care, Constr. Dept., Chile Exploration Co., Chuquicamata (*via* Antofagasta), Chili.

PEARSON, HARRY BROWNLEY, JR. Asst. Engr., H. C. Frick Coke Co., Scottdale, Pa.

PEEK, JESSE HOPE. 115 East St. Catherine St., Louisville, Ky.

RAKESTRAW, CHARLES LYSANDER. 5102 West St., Oakland, Cal.

RICHARDS, GEORGE WILLIAM. 1526 Frick Bldg., Pittsburgh, Pa.

RICHARDS, WALTER ALAN. Care, Hardaway Contr. Co., Electric, N. C.

RIMBAULT, EMILE LEONARD, JR. 556 West 191st St., New York City.

ROBINSON, RUSSELL MOORE. Care, Clinchfield Products Corporation, Johnson City, Tenn.

ROSE, ALSTON ORANGE. Asst. Engr., J. F. Witmer Co., 314 South 6th St., Ironton, Ohio.

JUNIORS (*Continued*)

SEGURA, VALERIANO. Dist. Engr., Bureau of Public Works, Manila, Philippine Islands.

SERRA, JULIUS HERSCHEL. 1578 East 22d St., Brooklyn, N. Y.

SMITH, HERSCHEL C. Poteau, Okla.

SMITH, RICHARD BENNETT. Structural Draftsman, C., C., C. & St. L. Ry., Chf. Engr.'s Office, Cincinnati, Ohio.

SOUTHER, MORTON EDWIN. 2231 Knapp St., St. Paul, Minn.

SPANGLER, LYSLE ENOCH. Asst. Supt., Constr., Potash Plant, for Hercules Powder Co., Box 139, Chula Vista, San Diego, Cal.

STANFORD, JAMES LELAND. Hamilton, Ga.

STOW, FREDERIC STEVENS. Roxbury, Conn.

TAYLOR, GEORGE BLANEY. Designing Engr., Berlin Constr. Co., Berlin (Res., 96 Harrison St., New Britain), Conn.

THORNTON, CHARLES EDWARD. Care, Virginia Lead & Zinc Corporation, Jones Store P. O., Va.

TOMS, JAY WILLIAM. 1515 Great Northern Bldg., Chicago, Ill.

VAN NESS, RUSSELL ALGER. Structural Draftsman, Am. Bridge Co., 545 Harrison St., Gary, Ind.

VEATCH, FRANCIS MONTGOMERY. Care, Eng. Dept., State Board of Health, Lawrence, Kans.

WAITE, EARLE CHESTER. Civ. Engr., Vice-President's Office, Bethlehem Steel Co., University Heights, South Bethlehem, Pa.

WARD, GEORGE SPARKMAN. Care, Beebe & Tull, Spartanburg, S. C.

WARRACK, JAMES BALDWIN. Engr. and Contr. (Warrack Constr. Co.), 431 Lyons Bldg., Seattle, Wash.

WAY, WILLIAM FLOYD. 4730 Eleventh Ave., N. E., Seattle, Wash.

WERNECKE, CHAUNCY. 4546 Eighteenth Ave., N. E., Seattle, Wash.

WHITE, ROY ALLERT. R. F. D. No. 7, Coldwater, Mich.

WILLCOX, HENRY. Asst. Supt., Kalmus, Comstock & Westcott, 9 Harcourt St., Boston, Mass.

RESIGNATIONS

ASSOCIATE MEMBERS	Date of Resignation.
CAMERON, KENNETH MACKENZIE	June 30, 1916
JUNIORS	
AFFLECK, MYRON HOPKINS STRONG	May 19, 1916

DEATHS

ARGOLLO, MIGUEL DE TIEVE E. Elected Member October 2d, 1895; died May 14th, 1916.

CARTLIDGE, CHARLES HOPKINS. Elected Member, May 4th, 1904; died June 14th, 1916.

COFFIN, AMORY. Elected Member March 3d, 1875; died June 5th, 1916.

CONKLING, CLOUD CLIFFORD. Elected Member, January 4th, 1905; died May 8th, 1916.

CONLON, FRANK JOSEPH. Elected Associate Member, March 2d, 1915; died June 28th, 1916.

CORTHELL, ELMER LAWRENCE. (*President.*) Elected Member, September 2d, 1874; died May 16th, 1916.

CUNNINGHAM, DAVID WEST. Elected Member, May 7th, 1873; died May 10th, 1916.

FLOY, HENRY. Elected Member, June 6th, 1911; died May 5th, 1916.

HALL, HENRY ARTHUR. Elected Member May 7th, 1902; date of death unknown.

HILL, JAMES JEROME. Elected Fellow, January 10th, 1889; died May 29th, 1916.

KUNZ, FREDERIC CHARLES. Elected Associate Member, February 6th, 1895; Member, December 7th, 1898; died May 3d, 1916.

MCKENZIE, THEODORE HALL. Elected Member, September 7th, 1881; died May, 1916.

MCMULLEN, STANLEY HASTINGS. Elected Associate Member, November 3d, 1915; died July 12th, 1916.

MAIS, HENRY COATHUPE. Elected Member, June 6th, 1883; died February 25th, 1916.

OSGOOD, JOSEPH OTIS. Elected Junior, May 3d, 1876; Member, March 5th, 1879; died June 28th, 1916.

ROCKWELL, JAMES VINCENT. Elected Junior, April 3d, 1900; Associate Member, February 4th, 1903; Member, November 5th, 1907; died May 24th, 1916.

ROHWER, HENRY. Elected Member, April 1st, 1903; died May 4th, 1916.

SCHLAFLY, ROY KARL. Elected Associate Member, September 3d, 1913; date of death unknown.

SOOYSMITH, CHARLES. Elected Member, May 5th, 1886; died June 1st, 1916.

WHITTEMORE, DON JUAN. (*Past-President.*) Elected Member, July 10th, 1872; Honorary Member, January 6th, 1911; died July 16th, 1916.

Total Membership of the Society, August 3d, 1916, 8 033.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(May 2d, to July 22d, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings,* Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal,* Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal,* Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions,* Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly,* Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur,* München, Germany.
(8) *Stevens Institute Indicator,* Hoboken, N. J., 50c.
(9) *Engineering Magazine,* New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News,* New York City, 15c.
(14) *Engineering Record,* New York City, 10c.
(15) *Railway Age Gazette,* New York City, 15c.
(16) *Engineering and Mining Journal,* New York City, 15c.
(17) *Electric Railway Journal,* New York City, 10c.
(18) *Railway Review,* Chicago, Ill., 15c.
(19) *Scientific American Supplement,* New York City, 10c.
(20) *Iron Age,* New York City, 20c.
(21) *Railway Engineer,* London, England, 1s. 2d.
(22) *Iron and Coal Trades Review,* London, England, 6d.
(23) *Railway Gazette,* London, England, 6d.
(24) *American Gas Light Journal,* New York City, 10c.
(25) *Railway Mechanical Engineer,* New York City, 20c.
(26) *Electrical Review,* London, England, 4d.
(27) *Electrical World,* New York City, 10c.
(28) *Journal,* New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal,* Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique,* Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux,* Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil,* Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines,* Paris, France.
(35) *Nouvelles Annales de la Construction,* Paris, France.
(36) *Cornell Civil Engineer,* Ithaca, N. Y.
(37) *Revue de Mécanique,* Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways,* Paris, France.
(39) *Technisches Gemeindeblatt,* Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung,* Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift,* Berlin, Germany.
(42) *Proceedings,* Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées,* Paris, France.
(44) *Journal,* Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age,* New York City, 10c.
(46) *Scientific American,* New York City, 15c.
(47) *Mechanical Engineer,* Manchester, England, 3d.
(48) *Zeitschrift,* Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen,* Berlin, Germany.
(50) *Stahl und Eisen,* Düsseldorf, Germany.
(51) *Deutsche Bauzeitung,* Berlin, Germany.
(52) *Rigasche Industrie-Zeitung,* Riga, Russia, 25 kop.
(53) *Zeitschrift,* Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions,* Am. Soc. C. E., New York City, $12.
(55) *Transactions,* Am. Soc. M. E., New York City, $10.

(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England, 6d.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(82) *Mining and Engineering World,* Chicago, Ill., 10c.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Iron Tradesman,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant,* Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Highway Bridge Floors.* Charles M. Spofford. (58) Dec., 1915.

The Erection of the New Quebec Bridge.* N. C. McMath. (36) Apr.

Plaza Improvements of the Manhattan Bridge, New York City.* C. N. Pinco. (36) May.

Billings Bridge over Rideau River, Ottawa, Ont., Canada.* L. McLaren Hunter. (114) No. 14, May.

Experience and Costs in Making Concrete-Bridge Units.* Horace M. Holmes. (13) May 4.

Highway Bridge Development in Ontario.* Geo. Hogarth. (Paper read before the Canadian and Inter. Road Congress.) (96) May 4.

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* Illustrated.

Bridges—(Continued).

Bridge Washouts in the Desert.* (13) May 11.
A New Ohio River Bridge at Metropolis.* (15) May 12.
Truss Deflections Accurately Determined by Angle Changes and Elastic Weights.* D. B. Steinman. (14) Serial beginning May 13.
Well-Balanced Mixing Plants Pour Dense Concrete from High Towers on Long Highway Bridge.* (14) May 13.
Details of Old Iron Viaduct in Service 37 Years.* Edgar K. Ruth. (13) May 18.
Steel Cantilever Ribs Balanced over Main Piers to Form Arched Concrete Spans.* (14) May 20.
Railroad Bridge Piers Built both Ways from Central Plant on Island.* (14) May 20.
Queensboro Bridge Floor Strengthened by Adding Stiffeners to Buckle Plates.* (14) May 20.
Methods and Costs of Constructing a Small Bridge Pier in the Potomac River.* Elliott Vandevanter. (86) May 24.
The Season's Work on the Quebec Bridge.* A. J. Meyers. (15) May 26; (46) May 6; (96) June 1; (12) June 16.
Bridge Eye-Bar Failure at Spokane. (21) June.
Erection of Old Trails Bridge over Colorado River.* J. A. Sourwine. (13) June 1.
Norfolk's Ferro-Concrete Bridges.* (104) June 2.
Double Reinforcement in Monier Arch Patent. (14) June 3.
How Steel Prices Affect Cost of Minnesota Bridge Work. (14) June 3.
Concrete Viaduct with Special Expansion Provisions.* Charles W. Martin. (13) June 8.
Plate Girders of Record Weight in Worcester Viaduct.* F. B. Freeman. (13) June 8.
Pressed-Steel Floor Forms Left in Place on Two-Mile Bridge Eliminates Carpenters.* (14) June 10.
Pennsylvania Railroad Bridge at Phoenixville.* (15) June 16.
Steel Truss Spans Raised More than 6 Feet without Interruption to Traffic.* (14) June 17.
Concrete Viaduct Versus Fill for Street Elevation.* (13) June 22.
Steel I-Beams and Concrete Highway Bridges.* (13) June 22.
Wheel-Load and Impact Charts for Railway Bridges. D. B. Steinman. (13) June 22.
Washout at Abutment Drops Train from Bridge.* (13) June 22.
Swing Bridge Over the Little Calumet River.* (15) June 23.
Appearance of Brooklyn-Brighton Viaduct, Cleveland, Improved by Special Features.* (14) June 24.
Long Truss Highway Bridges, Utah Road Standards.* (13) June 29.
New Form of End Lift Used on Chelsea North Draw.* Randall D. Gardner. (13) June 29.
Pitt River Reinforced-Concrete Arch in California.* (13) June 29.
The New Thames River Bridge at New London, Conn.* (15) June 30.
Charing Cross Bridge.* (12) Serial beginning June 30.
New Reinforced Concrete Bridge at Houston.* J. L. Jacobs. (67) July.
Special Plant Layout Expedites Construction of Brooklyn-Brighton Viaduct.* (14) July 1.
Temporary Bascule Bridge for Construction Purposes.* H. DaCamara. (13) July 6.
Cheap Devices Used in Reconstructing Truss Bridges Eliminate Costly Centering.* E. J. Doyle. (14) July 8.
Tower and Derrick on Same Boat in Concrete Plant for Bridge.* A. Frederickson. (14) July 8.
Three-Mile Concrete Causeway Which Saves Thirty Miles of Travel.* (46) July 8.
Bridge Across the Ohio River at Metropolis, Ill.* (18) July 8.
Finish Deep Bridge Substructure, Designed to Reduce Work Under Water, Month Ahead of Time.* Frank M. Cortelyou. (14) July 8.
Tests of Large Bridge Struts Reveal New Facts.* (13) July 13.
K-Truss Bridge of Santa Fe Across Arkansas River.* (13) July 20.
The Reconstruction of the Keokuk Bridge.* (15) July 21.
L'Etat des Travaux du Pont de Québec sur le Saint-Laurent (Canada).* P. Caifas. (33) June 3.
Bogenbrücken aus umschnürtem Gusseisenbeton.* H. Nitzsche. (51) Serial beginning Sup. No. 5.
Neubau der Thurbrücke bei Gütighausen.* A. Rohn. (107) Apr. 1.
Die Drahtseil-Hängebrücke bei Landquart.* A. Walther. (107) May 20

Electrical.

Electric Service Problems and Possibilities.* P. Junkersfeld. (58) Mar.
Power Station Building.* James N. Hatch. (4) Mar.
Universal Electricity Supply. Samuel Insull. (58) Mar.

* Illustrated.

Electrical—(Continued).

Magnetisation by Rotation.* S. J. Barnett. (From the *Physical Review*.) (73) Apr. 21.
A Large Battery Sub-Station.* (26) Apr. 21.
A Plea for the Standardisation of Switchgear. J. P. C. Kivlen. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) Apr. 28.
Mechanical Tamping of Trench Backfill (for Telephone Conduit).* C. W. Wilson. (60) May.
The Municipal Lighting Plant of Detroit, Michigan.* (60) May.
Suggestions for Electrical Research in Engineering Colleges. V. Karapetoff. (42) May.
The Use of Continuous Current for Terminal and Trunk Line Electrification.* Norman Wilson Storer. (77) May 1.
Hire and Maintenance of Continuous-Current Motors. Henry Joseph. (77) May 1.
Municipal Power Plant Operated by Saskatoon, Canada.* A. G. Christie. (64) May 2.
Losses in Continuous-Current Motors and Generators.* A. M. Bennett. (64) May 2.
The Rennerfelt Electric Arc Furnace.* C. H. Vom Baur. (Paper read before the Am. Electrochemical Soc.) (20) May 4; (47) May 26.
Remington Arms Power Plant at Bridgeport.* (20) May 4.
A Rotary Converter Installation.* E. P. Austin. (26) May 5.
Small Electric Stations. Louis J. Lawless. (Paper read before the Eng. and Scientific Assoc. of Ireland.) (104) May 5.
New Aviation Beacons That Make Safe the Landing of Aircraft at Night.* Robert G. Skerrett. (46) May 6.
Growth of a Combination Utility in a Small City. Arthur Curtis Scott. (27) May 6.
Great Electro-Magnets.* A. Cotton. (From *Revue Generale des Sciences Pures et Appliquees.*) (19) Serial beginning May 6.
Effects of Electrolysis on Underground Piping Systems. Albert F. Ganz. (Paper read before the Inter. Eng. Congress.) (19) May 6.
Parallel Operation of Alternators.* L. J. Corbett. (111) May 6.
Large Increase in Central Station Business. (27) May 6.
Carondelet Power Plant.* Thomas Wilson. (64) May 9.
Electrical Winding Plant in Scotland.* (12) May 12.
Installation of a Special Pole-Top Regulator. (27) May 13.
Installation Features at Alexandria, Va., Steam Station (Electric Plant).* Francis R. Weller. (27) May 13.
Operating Data from Two Kansas Plants. (27) May 13.
A New Triangulation Signal Lamp.* E. G. Fischer. (111) May 13.
Installation of Lighting Units in Power Stations.* M. M. Samuels. (27) May 13.
Performance of 30 000-Kw. Steam Turbo-Generators.* (27) May 13.
Electric Furnace Development at Niagara Falls. F. J. Tone. (Paper read before the Am. Electrochemical Soc.) (82) May 13.
Induction Motor Characteristics. H. M. Phillips. (64) May 16.
The Electric Lighting of Small Towns. H. N. Munro. (Paper read before the Junior Institution of Engrs.) (104) May 19; (47) May 26; (26) June 9; (73) June 16.
Third Harmonics in the Phase Pressure of Three-Phase Alternators with Cylindrical Rotors.* A. E. Clayton. (73) May 19.
The Production of Constant High Potential with Moderate Power Capacity.* A. W. Hill. (Abstract from *General Electric Review.*) (73) May 19.
Electric Enterprises in Japan.* (111) May 20.
Electric Service to Interconnected Illinois Towns.* (27) May 20.
The Trend of Central Station Development.* L. A. Ferguson. (27) May 20.
The Rennerfelt Electric Furnace.* Alfred Stansfield. (Abstract from Report to the Dept. of Mines of Canada.) (19) May 20.
Telephonometry.* B. S. Cohen. (Abstract of paper read before the Institution of Post Office Elec. Engrs.) (73) Serial beginning May 26.
Photometry of the Gas-Filled Lamp.* G. W. Middlekauff and J. F. Skogland. (Abstract from *Scientific Papers,* Bureau of Standards.) (73) May 26.
The Determination of the Dimensions of Commutators. Thomas Carter. (73) May 26.
Electrically Driven Paper Mill.* Thomas Wilson. (64) May 30.
The Corona Voltmeter.* J. B. Whitehead and M. W. Pullen. (42) June; (27) June 17.
Protection of High-Voltage Distribution Systems by Isolating Transformers. O. O. Rider. (42) June.
Megger and Other Tests on Suspension Insulators. F. L. Hunt. (42) June.
Electric Drive for Reversing Rolling Mills.* Wilfred Sykes and David Hall. (42) June.
Experiences in Testing Porcelain. E. E. F. Creighton. (42) June.

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* Illustrated.

Electrical—(Continued).

A New Method of Grading Suspension Insulators.* R. H. Marvin. (42) June.
The Electricity Supply of Great Britain.* Ernest T. Williams. (77) June.
Report of the Transmission Committee: I-Data from Operating Plants on the Effect of Altitude on the Operating Temperature Rise of Electrical Apparatus.* Percy H. Thomas. (42) June.
Theory of Parallel Grounded Wires and Production of High Frequencies in Transmission Lines.* E. E. F. Creighton. (42) June.
Service Branches from Extra High-Tension Circuits. D. M. Macleod. (77) June.
Experience and Recent Developments in Central Station Protective Features.* N. L. Pollard and J. T. Lawson. (42) June.
How to Select Industrial Motors.* Thomas Robson Hay. (9) June.
Application of a Polar Form of Complex Quantities to the Calculation of Alternating-Current Phenomena.* N. S. Diamant. (42) June.
The Economical Production of Power from Coke-Oven Gas (for Electric Plants). G. Dearle. (77) June.
The Testing of Underground Cables with Continuous Current.* O. L. Record. (77) June.
Notes on Design of Electromagnetic Machines.* Stanley Parker Smith. (73) Serial beginning June 2.
Operation of an Ohio Interconnected System.* (27) June 3.
Final Hearing on National Electrical Safety Code. (27) June 3.
Quitman Municipal Water and Light Plant.* F. B. Crowell. (64) June 6.
Magnetic Amplifier for Radiotelephony.* E. F. W. Alexanderson and S. P. Mixdorff. (Abstract of paper read before the Inst. of Radio Engrs.) (73) June 9.
Electric Vehicle Progress.* (Papers read before the National Electric Light Assoc.) (26) June 9.
Electrical Switch-Gear for Industrial Purposes.* (11) June 9.
The Predetermination of Higher Harmonics in the Alternating Current Transformer when the Impressed E. M. F. is a Simple Harmonic Function of the Time. Geo. R. Dean. (73) June 9.
Electric Trucks in Government and City Service.* (27) June 10.
Methods for Working on Live High-Voltage Lines.* J. O. Hardin. (27) June 10.
A Recent Railway Substation.* G. C. Hecker. (17) Serial beginning June 10.
Installation Costs for Industrial Plant Substations.* N. Nesbitt Teague. (27) June 10.
Progress in Arc Lamp Technology.* Werner Bergs. (From *Prometheus.*) (19) June 10.
New Cincinnati Hospital Plant.* Thomas Wilson. (64) June 13.
An Electric Arc Furnace for Laboratory Use.* Oliver P. Watts. (105) June 15.
Municipal Electrical Extensions at Kilmarnock.* (26) Serial beginning June 16.
The Problem of the Small Generating Station.* Geo. Wilkinson. (73) June 16.
Alternating-Current Motors.* H. C. E. Jacoby. (Paper read before the Assoc. of Supervising Electricians.) (47) June 16.
Turbine-Driven Alternators.* (73) June 16.
Causes of Telephone Noise and Its Elimination.* Frank T. Coldwell. (27) June 17.
An Analysis of Vapor-Rectifier Losses.* William Tschudy. (From *Bulletin* des Schweizerischen Elektrotech Vereins.) (27) June 17.
Synchronous Gearing Mechanisms of Essential Importance in the Printing Telegraph.* (19) June 17.
Electric Truck Troubles. F. E. Whitney. (Paper read before the National Elec. Light Assoc.) (19) June 17.
Concrete Cells for Circuit Breakers and Busbars.* C. H. Sanderson. (27) June 17.
Unit No. 3 at Northwest Station.* Thomas Wilson. (64) June 20.
Principles of Phase Converter.* (64) June 20.
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Switchgear for Central Stations and Isolated Plants.* (73) June 23.
The Johannesburg Municipal Electric Power Station.* J. H. Dobson. (Abstract of paper read before the South African Institution of Engrs.) (47) Serial beginning June 23.
The Generation of Electricity on a Small Scale or Bulk Supply.* H. S. Ellis. (Abstract of paper read before the Incorporated Municipal Elec. Assoc.) (73) June 23.
Control Gear for Direct-Current Motors. E. F. Butler. (26) Serial beginning June 23.
Adjustable Speed Induction Motors.* (12) June 23.
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Railway Motor Field Control.* D. C. Hershberger. (Paper read before the Illinois Elec. Rys. Assoc.) (17) June 24.

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Electric Drive in Clay Product Manufacture.* Norman G. Meade. (27) June 24.
Devices for Protecting Armatures. R. H. Parsons. (17) June 24.
Operating Direct-Current Generators in Parallel.* H. G. Gibson. (64) June 27.
The Losses in Cables at High Frequencies.* Edwin F. Northrup and R. G. Thompson. (3) July.
Street Lighting Installation in Port Jervis, New York.* H. A. Tinson and D. M. Diggs. (From *General Electric Review.*) (60) July.
Analysis of Merrill Report on Water Power. (27) Serial beginning July 1.
Agricultural Uses of Power; Mt. Whitney Power and Electric Company's System.* S. T. Harding. (111) July 1.
Electricity Supply.* W. W. Lackie. (Abstract of paper read before the Institution of Engrs. and Shipbuilders.) (73) July 7.
Motor Drive for Steel Mills.* F. B. Crosby. (Abstract from the *General Electric Review.*) (73) July 7.
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Analysis of Moving Picture Theater Lighting.* L. W. McOmber. (27) July 15.
Street Lighting.* Waldo C. Cole. (111) July 15.
Selling Service to Mines.* Wightman D. Roberts. (27) July 22.
Conditions Under Which Oregon Company Burns Wood.* (27) July 22.
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Examen des Metaux par les Rayons X* H. Pilon. (93) Nov., 1915.
L'Unification des Isolateurs de Lignes Aériennes.* (33) Apr. 29.
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Gyroscopic Torque Apparatus.* E. Rawson. (12) Apr. 21.
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Oil-Engine Driven Steel Barge for River Freight Traffic.* (13) May 4.
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How Men Work in the Depths of the Sea, Facts Relating to Diving and Diving Apparatus.* (From the *Marine Engineer and Naval Architect.*) (19) May 27.
Lighterage. Henry L. Joyce. (65) June.
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La Bataille Naval du Jutland, l'Evolution des Marines anglaise et allemande avant la Guerre.* A. Poidlouë. (33) June 24.

Mechanical.

Compressed Air for Coal-Cutters* Sam Mavor. (106) Vol. 50, Pt. 4.
Gas-Producers at Collieries for Obtaining Power and Bye-Products from Unsaleable Fuel. Mansfeldt Henry Mills. (106) Vol. 50, Pt. 4.

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Economies in Coal Washing.* Sherwood Hunter. (Paper read before the Manchester Geological and Min. Soc.) (106) Vol. 51, Pt. 2.
The Cause and Effect of "Ghost Lines" in Large Steel Forgings.* J. O. Arnold. (75) Oct.-Dec., 1915.
The World's Supplies of Fuel and Motive Power.* Dugald Clerk. (74) Oct.-Dec., 1915.
The Theory of Grinding, With Reference to the Selection of Speeds in Plain and Internal Works.* James J. Guest. (75) Oct.-Dec., 1915.
Struts and Tie-Rods in Motion. H. Mawson. (75) Oct.-Dec., 1915.
Utilization of Iron and Steel Works' Slags.* E. C. Brown. (58) Jan.
Belt Conveyors.* A. Robertson and A. McArthur Johnston. (Paper read before the South African Institution of Engrs.) (57) Apr. 20; (16) July 1.
Coking, the Recovery and Working-Up of By-Products.* Christopher Barber. (Paper read before the Sheffield Univ. Gas and Coke Oven Students' Assoc.) (22) Serial beginning Apr. 21.
Lubrication in Practice. H. W. Petty. (Paper read before the Assoc. of Engrs. in Charge.) (47) Serial beginning Apr. 21.
The Installation and Erection of High-Speed Machinery. J. A. McLay. (Paper read before the Assoc. of Min. Elec. Engrs.) (22) Apr. 21.
Electric Welding and Brazing Apparatus.* (47) Apr. 28.
Fuel for Steam Boilers. William Kent. (Abstract of paper read before the Pan-American Scientific Congress.) (47) Apr. 28.
Steam Safety Valves.* George H. Clark. (55) May.
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How to Use Superheated Steam.* Charles L. Hubbard. (9) May.
Smoke and Soot.* James Scott. (21) May.
Features of Rolling Mill Reversing Engines.* W. Trinks. (116) Serial beginning May.
Labor-Saving Devices in the Machine Shop.* Albert A. Dowd. (9) May.
The Utilization of By-Products from the Manufacture of Coke. C. G. Atwater. (58) May.
Economy in Use of Blast Furnace Carbon. H. P. Howland. (116) May.
Meeting the Demands of Fire Brick Users.* Chas. S. Kinnison. (116) May.
Manufacture and Characteristics of Wrought Iron Pipe.* W. A. Phillis. (83) May 1.
Design and Operation of the Bunsen Gas Burner. G. C. Carnahan. (Paper read before the Illinois Gas Assoc.) (83) May 1.
Status of American By-Product Coke. Thomas C. Clarke. (Paper read before the Soc. of Chemical Industry.) (20) Serial beginning May 4; (105) May 1; (24) June 12.
Gas Company Accounts. V. V. Smith. (Paper read before the Indiana Gas Assoc.) (83) May 1; (24) May 8.
Manufacture of Sulphuric Acid.* Christopher Barber. (Paper read before the Sheffield Univ. Gas and Coke-Oven Students' Assoc.) (66) May 2.
The Effect of Salts on the Drying Behavior of Some Clays.* Homer F. Staley. (Paper read before the Am. Ceramic Soc.) (76) May 2.
The Burning of Porcelain. George H. Brown. (Paper read before the New Jersey Clayworkers' Assoc.) (76) May 2.
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New Bar Mill of Notable Flexibility.* (20) May 4.
A Plant for Conversion from Rifle to Locomotive Building.* (72) May 4.
Empirical Formulas for the Proportions of Lathes.* A. Lewis Jenkins. (72) May 4.
Machine Molding in a Jobbing Steel Foundry.* A. J. Abell. (20) May 4.
On Reduction Gears.* John H. Macalpine. (11) Serial beginning May 5.
Horizontal Boring, Drilling, and Milling Machinery.* (11) May 5.
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The Sulphur Impurity of Coal Gas. Frank Clowes. (Paper read before the Soc. of Chemical Industry.) (66) May 9.
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Building Single-Purpose Lathes in a Single-Purpose Shop.* Ethan Viall. (72) May 11.
New Expeditious Method of Baking Cores.* (20) May 11.
Oil Quenching Improves Solid Nickel-Steel Forgings.* C. J. Yarnall. (13) May 11.
The Manufacture of Large Forging Ingots.* Robert C. Woodward. (20) May 11.
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Natural Gas in Ohio.* J. A. Bownocker. (Paper read before the Cleveland Eng. Soc.) (83) May 15.
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The Yeadon and Guiseley Gas Company's Undertaking; the Old and New Plant. J. E. Lister. (Paper read before the Yorkshire Junior Gas Assoc.) (66) May 16.
Cleaning Condenser Tubes.* C. F. Hirshfeld. (64) May 16.
Analysis of Boiler Explosion at West River, N. B.* (64) May 16.
The Arrangement and Requirements of Elevators in Office Buildings. Cecil F. Baker. (From the *Architectural Record.*) (86) May 17.
Manufacture of Cartridge Brass.* C. R. Barton. (72) May 18.
Interpretation of Coal Analysis. E. G. Bailey. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 19; (25) June.
Proper Care of Cranes and Hoists. H. A. Shultz. (Paper read before the Industrial Welfare and Efficiency Conference.) (47) May 19.
A Study Concerning the Best Proportion for a Stream-Line Body.* F. W. Lanchester. (11) May 19.
Thorium, How It Is Extracted for Making Gas Mantles. Thurston Owens. (From the *Chemical Engineer.*) (19) May 20.
A Comparison of Modern Coal Carbonization Plants.* Vernon Baker. (Paper read before the Indiana Gas Assoc.) (24) May 22; (83) May 1.
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Symposium on Welding as Applied to Boilers. (64) May 23.
Oil Washing for the Absorption of Tolnol and Benjol.* Thomas Glover. (66) May 23.
General Electric Oil Engines for United States Government.* Alfred D. Blake. (64) May 23.
Proportioning Cylinder Ratio in Compound Engines.* R. L. Wales. (64) May 23.
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Application of Cranes in the Foundry.* T. Everett Austin. (Paper read before the Newark Foundrymen's Assoc.) (20) May 25.
An Improved Design in Coke Ovens.* (20) May 25.
Rational Design of Foundation Anchor Plates.* Terrell Croft. (72) May 25.
New Coke Ovens at Port Clarence Works.* (22) May 26.
Coal Distribution Record System.* J. G. Crawford. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 26; (18) May 20.
The Steam Boiler of 1915.* Arthur D. Pratt. (Abstract of paper read before the Inter. Eng. Congress.) (47) Serial beginning May 26.
Ash, Clinker and Dust Separators.* M. Buhle. (From *Glückauf.*) (57) May 26.
Coal Transfer and Preparation Plant of the East Broad Top R. R. & Coal Co.* (18) May 27.
Steam Power for Aeroplanes. James G. Dudley. (19) May 27.
Rust Deposits in Gas Mains and Services. A. F. Kersting. (Paper read before the Southern Gas Assoc.) (24) May 29.
Supplement to Paper on Rust Deposits. J. W. Lansley. (24) May 29.
Mechanical Soot Blowers. P. V. Stephens. (Abstract.) (64) May 30.
Silica and Fireclay Materials.* John West. (Paper read before the Manchester District Institution of Gas Engrs.) (66) May 30; (22) June 16.
Cost of Coal and Oil as Fuel. Perry Barker. (64) May 30.
Gearless Traction Elevators.* (64) May 30.
Economical Load on Boilers.* Haylett O'Neill. (64) May 30.
Increasing Thermal Efficiency of Automobile Engines.* C. E. Sargent. (Paper read before the Soc. of Automobile Engrs.) (64) May 30.
Handling Coal and Ashes at Northwest Station.* Thomas Wilson. (64) May 30.
Cost Determinations of 22-In. Steel Pipe Manufacture. H. A. Whitney. (86) May 31.
Report Upon Efficiency Tests of a 30 000-Kw. Cross-Compound Steam Turbine.* H. G. Stott and W. S. Finlay, Jr. (55) June.

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Advancement in Underground Ore Lading.* M. E. Richards. (116) June.
Refining Vegetable and Animal Oils. Charles Baskerville. (3) June.
A Steam Flow Meter.* (25) June.
A Modern Hydrated Lime Plant.* Richard K. Meade. (67) June.
Steel Production at New Minnesota Plant.* Charles C. Lynde. (116) June.
The Economics of Material Handling in Manufacturing Plants.* Reginald Trautschold. (9) Serial beginning June.
By-Products Recovery in Coke Production. W. H. Childs. (Paper read before the Am. Iron and Steel Inst.) (116) June.
Two Welded Gas Mains Laid under Brazos River.* (13) June 1.
Automatic Manufacturing Miller with Receding Table.* (72) June 1.
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Originality in a Hartford Machine Works.* (20) June 1.
Gasoline from Natural Gas by Absorption Methods. G. A. Burrell, P. M. Biddison and G. G. Oberfell. (Paper read before the Natural Gas Assoc.) (83) June 1; (105) June 1.
Drop Forging the Russian Cruciform Bayonet.* John H. Van Deventer. (72) June 1.
North Carolina has 3 800- and 4 200-Ft. Cableways.* (13) June 1.
Electric Welding in Boiler Repairs. Frank McManamy. (Paper read before the Boiler Makers' Assoc.) (15) June 2.
The Casting of Non-Ferrous Metals in Chill Moulds.* F. Johnson. (Abstract of paper read before the British Foundrymen's Assoc.) (47) June 2.
Coal and Shipping.* F. J. Warden-Stevens. (57) Serial beginning June 2.
Plain Facts About Kerosene Carburetors.* Victor W. Page. (46) June 3.
Operating Cost Records Show Comparative Economy of 65 Motor Vehicles in Los Angeles Water Department.* Burt A. Heinly. (14) June 3.
Pumping Costs with Diesel Engines Given in Detail.* H. W. Gochnauer. (14) June 3.
Handling Retail Coal in a Concrete Cylinder Plant.* Charles H. Higgins. (45) June 3.
Utilization of Gas Oil.* R. C. Downing. (Paper read before the Illinois Gas Assoc.) (24) Serial beginning June 5.
Performance of Uniflow Engine and Turbine Compared.* L. A. Quayle. (64) June 6.
The Exhaust Steam Turbine.* J. Breslav. (64) June 6.
Foreign Gases in Refrigeration. H. J. Macintire. (64) June 6.
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The Application of Coal Gas to the Purpose of Illumination. William Thomas Brande. (From the *European Magazine*, May, 1816). (66) June 6.
How Do You Buy Coal? Carleton H. Hubbard. (Paper read before the New Jersey Clay Workers' Assoc.) (76) June 6.
Some Notes on Fuel Economy. John W. Lee. (Paper read before the Yorkshire Junior Gas Assoc.) (66) June 6; (22) June 23.
Impure Boiler Waters. William N. Berkeley. (64) June 6.
Lubricating Oils and Cutting Compounds for Shop Use. W. Rockwood Conover. (72) June 8.
Manufacture of Motor Truck Worm Drives.* F. L. Prentiss. (20) June 8.
Measuring Locomotive Coal.* (13) June 8.
A Steel Freight Container.* (15) June 9.
The Automobile and the City Plan. Nelson P. Lewis. (Abstract of paper read before the National Conference on City Planning.) (14) June 10.
The Manufacture and Use of High Speed Steel. Henry D. Hibbard. (Abstract from *Bulletin* of the U. S. Bureau of Mines.) (18) June 10; (47) July 7.
Testing Safety Valves at the Naval Engineering Experiment Station.* J. L. Kauffman. (64) June 13.
Diagram for Computing Flow of Steam in Pipes.* Howard Harding. (64) June 13.
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Report of the Refractory Materials Research Committee of the Institution of Gas Engineers. (66) June 13.
Practical Tests of Steam-Flow and Water Meters. E. G. Bailey. (Paper read before the National District Heating Assoc.) (64) June 13.
Report of Life of Gas-Meters Research Committee of the Institution of Gas Engineers. (66) June 13.
The Action of Air in Surface Condensers.* Paul A. Bancel. (64) June 13.
Report of Station Operating Committee of the National District Heating Association on Boiler Operation.* (64) June 13.
The Plant Crew Reduces Ash-Handling Costs.* A. A. Norrman. (64) June 13.
Tractor with Ball Bearings in Endless Tread.* (13) June 15.
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Welding of Joints in Gas Main Construction. F. L. Hadley. (Paper read before the Natural Gas Assoc.) (83) June 15.

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The Factory Transportation of Product and Materials. W. Rockwood Conover. (72) June 15.
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Traveling Tower Cantilever Crane for Yard Service.* (13) June 15.
Determining the Capacity of Compressors.* Paul Diserens. (20) June 15.
Coke as a Reducing Agent in the Electric Smelting Furnace. R. C. Gosrow. (105) June 15.
Manganese Steel Welding.* P. A. E. Armstrong. (17) June 17.
Regulation of Weight, Size and Speed of Vehicles has Become an All-Important Problem.* H. C. Hutchins. (14) June 17.
Testing and Filtering of Transformer Oil. E. P. Peck. (27) June 17.
Substitutes for Coal in the Andes.* Benjamin L. Miller and Joseph T. Singewald, Jr. (45) June 17.
Operating Costs for Several Diesel Engine Installations.* (27) June 17.
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Purchasing Coal by Test. W. D. Stuckenberg. (Abstract of paper read before the Missouri Public Utilities Assoc.) (64) June 20.
Margin of Power in Internal Combustion Engines. R. E. Mathot. (64) June 20.
Burning No. 3 Buckwheat Coal on a Coxe Stoker. B. B. Hood. (64) June 20.
Horizontal and Vertical Baffling.* S. H. Viall. (64) June 20.
Coal Tar and Ammonia.* Thomas Gray. (Paper read before the Waverley Assoc. of Gas Managers.) (66) June 20.
A Notable Machine Shop of Moderate Size.* W. E. Freeland. (20) June 22.
Building Interchangeable-Part Lathes.* O. J. Abell. (20) June 22.
Large Wheel-Type Excavator.* (13) June 22.
Hobbing High Prime-Number Spurgears Without Special Mechanism.* Will O. Wynne. (11) June 23.
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Boiler House Design and Operation. W. W. Lackie. (Paper read before the Incorporated Municipal Elec. Assoc.) (73) June 23; (26) June 30.
The Wire Rope and the Coal Mine.* James Steelman. (45) June 24.
The Effect of Dissolved Salts in Feed Water. John B. C. Kershaw. (64) June 27.
Engine-Room Lubrication. George A. Townsend. (64) June 27.
The Carbonization of Pitch. E. W. Smith. (Paper read before the Midland Junior Gas Assoc.) (66) June 27.
Operating the Carbon-Dioxide Refrigerating Machine.* F. T. Flenniken. (64) June 27.
Refrigeration Plant Regulations, New York and Detroit.* (64) June 27.
Roll Pressures in Cold-Rolling Steel.* William K. Shepard and George C. Gerner. (72) June 29.
Steel Scrap in Various Foundry Mixtures.* G. S. Evans. (20) June 29.
Cable Tramways Used on Construction Work.* (13) June 29.
Malleable Iron, Its Characteristics, Uses and Abuses. Enrique Touceda. (Abstract of paper read before the Pittsburgh Ry. Club.) (47) June 30.
Internal-Combustion-Driven Electrical Sets. W. A. Tookey. (Paper read before the Assoc. of Supervising Electricians.) (47) June 30.
The Production and Use of Power and Its Relation to Fuel Economy. G. Stanley Cooper. (22) Serial beginning June 30.
Some Boiler Problems and Their Solutions. B. Thompson. (Paper read before the Stoke-on-Trent Engrs.' Assoc.) (47) Serial beginning June 30.
A Novel Method of Handling Boilers to Prevent Corrosion and Scale. Allen H. Babcock. (55) July.
Recovery of Potash at the Security Cement Plant.* (67) July.
Capacity and Economy of Multiple Evaporators.* E. W. Kerr. (55) July.
Machinery for Package Freight Handling.* R. H. Rogers. (From *General Electric Review.*) (108) July.
Steam Lubrication of Construction Machinery.* S. E. Lawrence. (100) July.
Heat Treatment for Drop Forged Steels. W. C. Peterson. (Paper read before the Drop Forge Assoc.) (62) July.
Scale Removal from Drop Forged Parts. W. C. Lytle. (Paper read before the Am. Drop Forge Assoc.) (62) July.
How to Use the Oxy-Acetylene Process. Henry Cave. (9) July.
Electric Arc for Welding Tool Steel Tips.* C. B. Auel. (62) July.
Dynamical Stability of Aeroplanes. Jerome C. Hunsaker. (From *Proceedings* of the National Academy of Sciences.) (19) July 1.
The Field for New Achievements in the Motor Vehicle Industry. Marins C. Krarup. (46) July 1.
The Preparation of Bituminous Coal.* Andrews Allen. (Paper read before the Kentucky Min. Inst.) (45) July 1.

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A New Portable Coke Loader.* L. R. W. Allison. (45) July 1.
Belt and Bucket Elevators.* Arthur O. Gates. (16) July 1.
A New Design of By-Product Gas Oven.* William Feicks. (83) July 1.
Stopping the Waste of a Scove Kiln.* (76) July 4.
The Path to Success in Operating a Continuous Coal-Fired Tunnel Kiln. A. F. Greaves-Walker. (76) Serial beginning July 4.
Thermal Problems for Gas Engines. Norton H. Humphrys. (66) Serial beginning July 4.
The Pyrometer a Cost-Cutting Agent. C. O. Arbogust and L. J. Sheridan. (76) Serial beginning July 4.
Aerial Tramway as Substitute for a Bridge.* (13) July 6.
Half-Hour Performances of 4-Wheel Scrapers. (13) July 6.
Dispatch System of Norton Grinding Company.* (20) July 6.
Influence of Viscosity in Pumping Crude Oil. Arthur L. Collins. (13) July 6.
Steel Storage in a Hartford Factory.* (20) July 6.
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The Steam Flow Into a Compound Steam-Turbine. (11) July 7.
The Miracle of Motor Transport.* Joseph Brinker. (46) July 8.
High Turbine Economy at Poor Load Factors.* (27) July 8.
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Introduction of Electromagnetic Separators Marked Increase in Quality and Quantity of Monazite Output (for Gas Mantles).* Reginald Gordon. (24) July 10.
Purchase and Inspection of Leather Belting. (72) July 13; (16) July 1.
Anchor-Bolt Holes Drilled by Gasoline-Air Outfit.* H. L. Hicks. (13) July 13.
Chicago Station has 45 000-H.p. Steam Turbine.* (13) July 13.
Building Up Industrial Fuel Business. S. Tully Willson. (Paper read before the Southern Gas Assoc.) (83) July 15.
General Principles of Workroom Lighting. A. L. Powell. (Paper read before the Am. School Hygiene Assoc.) (83) July 15.
Restoration of Gas Mains Over Rapid Transit Tunnels.* J. E. Worsley. (83) Serial beginning July 15.
Description of Pintsch-Bolz Vertical Producers.* W. Schwelzer. (From *Journal für Gasbeleuchtung.*) (83) July 15.
The Merits of Oil and Grease Lubrication. W. J. Fouhy. (82) July 15.
Temporary Pipes Along Curb and on Trestles Over Street Carry Good Part of New York City's Gas Supply During Subway Construction.* C. N. Green. (24) July 17.
A Method of Cutting Cams.* F. P. Ampudia. (72) July 20.
Some Foundry Practice in a Connecticut Plant.* Frank A. Stanley. (72) July 20.
Powdered Coal Burning.* (20) July 20.
Jigs and Tools Used in Making Pipe and Other Wrenches.* Ethan Viall. (72) July 20.
A Machine Shop with Notable Features.* (20) July 20.
Uniflow Engine for Rod Mill.* O. J. Abell. (20) July 20.
Arrangement and Maintenance of Machine Tools. W. Rockwood Conover. (72) July 20.
Recording the Performance of Large Boiler Units. Gilbert Rutherford. (27) July 22.
La Manutention Mécanique des Combustibles dans les Dépôts de la Compagnie d'Orléans.* L. de Boysson. (33) Apr. 22.
Fabrique de Ciment et de Chaux Hydraulique à Casablanca (Maroc).* Ch. Dantin. (33) Apr. 29.
L'Emploi du Charbon Pulverisé pour le Chauffage des Fours Sidérurgiques.* Ch. Dantin. (33) June 10.

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Addendum on Alloys of Iron and Molybdenum.* Sir Robert A. Hadfield. (75) Oct.-Dec., 1915.
The Chemical and Mechanical Relations of Iron, Molybdenum, and Carbon.* J. O. Arnold and A. A. Read. (75) Oct.-Dec., 1915.
The Zinc Smelter of To-day. F. E. Pierce. (58) Feb.
Rustless Ferro-Alloys.* Leslie Aitchison. (12) Serial beginning Apr. 21.
A Pre-Heated Blast Cupola. J. A. Parsons. (Paper read before the South African Institution of Engrs.) (47) Apr. 28.
Cyanidation at the Comacaran Mine, Salvador.* A. B. Peckham. (103) Apr. 29.
Flotation Practice in Missouri. L. A. Delano. (103) Apr. 29.
Working Data on Electrolytic Precipitation.* P. H. Crawford. (103) Apr. 29.
Recent Progress in Flotation. Robert J. Anderson. (3) May.
Review of Recent Progress in Electrolytic Iron. Oliver W. Storey. (Paper read before the Am. Electrochemical Soc.) (105) May 1; (47) June 23.

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Cost Accounting in the Construction and Operation of a Copper Smelter. Ernest Edgar Thum. (105) Serial beginning May 1.
Electric Furnace Products. F. J. Tone. (Paper read before the Am. Electrochemical Soc.) (105) May 1.
The Calculation of the Burden of the Blast Furnace. J. E. Johnson, Jr. (105) May 1.
Simple Tungsten Steel. Henry D. Hubbard. (*Bulletin,* U. S. Bureau of Mines.) (47) May 5.
Ferro-Concrete Bunkers at the Brymbo Works, Wrexham.* F. C. Coleman. (57) May 5.
The Double Roasting Process at East Helena. X. (103) May 6.
Chloridizing and Leaching Plant of Virginia Smelting Co.* F. A. Eustis. (16) May 6.
Quicksilver Reduction. Herbert Lang. (103) May 13.
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How Flotation Works.* G. D. Van Arsdale. (16) May 13.
Soap as a Frothing Agent in Flotation. M. H. Thronberry. (103) May 13.
Some Faults of the Small Electric Arc Furnace for Melting and Refining Steel. W. M. McKnight. (Paper read before the Am. Electrochemical Soc.) (111) May 13; (82) May 20.
Electrolysis of Alkaline Solutions of Potassium Sulphocyanate. Walton J. Crook, L. E. Booth and Arthur Thiel. (105) May 15.
Flotation and Cyanidation. (105) May 15.
Blast Furnace Operation. J. E. Johnson, Jr. (105) May 15.
Bethlehem's New Electric Steel Plant.* (20) May 18.
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Mechanical Feeding as Applied to Silver-Lead Blast Furnaces.* L. Douglass Anderson. (16) May 20.
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Vicosity of Furnace Slags.* (20) May 25; (116) June.
Tin Smelting at Perth Amboy, N. J.* Richard H. Vail. (16) May 27.
The Dry Chlorination of Complex Ores.* S. A. Ionides. (103) May 27.
The Roitsheim-Remy Continuous Zinc Distillation Process.* M. Liebig. (Tr. by Oliver C. Ralston from *Metall und Erz.*) (105) June 1.
The Distribution of Silver Between Metallic Lead and Litharge-Containing Slags. Boyd Dudley, Jr. (105) Serial beginning June 1.
The Electric Furnace in Steel Manufacture. John A. Mathews. (Paper read before the Am. Iron and Steel Inst.) (20) June 1; (22) June 23; (47) June 23; (116) June.
The Distribution of the Charge Column and of the Ascending Gas Columns (in a Blast Furnace). J. E. Johnson, Jr. (105) June 1.
Distribution of Raw Materials in the Blast Furnace.* George W. Vreeland. (Paper read before the Am. Iron and Steel Inst.) (20) June 1; (116) June.
Controlling Piping and Segregation in Steel Ingots. Henry M. Howe. (Paper read before the Am. Iron and Steel Inst.) (47) June 2.
Variable Factors in Malleable Iron Production.* L. E. Gilmore. (Paper read before the Am. Foundrymen's Assoc.) (47) June 2.
The Flotation Process at Goldfield, Nevada. A. H. Martin. (82) June 3.
Roasting and Acid-Making at Braden, Chile.* (Abstract from *Teniente Topics.*) (103) June 3.
The Economical Use of Blast Furnace Gas.* (20) June 8.
The Roasting of Blende. Maurice de Lummen. (From the *Chemical Trade Journal.*) (16) June 10.
The Cerro de Pasco District, Peru.* Joseph T. Singewald, Jr. and Benjamin Le Roy Miller. (16) June 10.
The Sherardizing Process. Oliver W. Storey. (105) June 15.
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Flotation Oils. O. C. Ralston. (105) June 15; (103) June 10; (82) June 10.
Extraction of Gold and Silver from Matte by Lead. W. Mostowitsch. (Tr. from *Journal* of the Russian Metallurgical Soc.) (105) June 15.
Flotation Versus Cyanidation. Jackson A. Pearce. (105) June 15.
Electric Furnace Melting of Ferro-Alloys. R. S. Wile. (Abstract of paper read before the Am. Electrochemical Soc.) (73) June 16.
Milling and Smelting at Humboldt, Arizona.* W. A. Scott. (82) June 17.
Flotation Process at the Standard Mill, Silverton, B. C.* James G. Parmalee. (82) June 17.
Brittle Annealed Copper. W. E. Ruder. (Abstract of paper read before the Am. Electrochemical Soc.) (47) June 23.
The King Process of Refining Copper.* (82) June 24.
Mill Equipment of the Engels Copper Mining Co.* W. A. Scott. (82) June 24.
Malleable Iron, Its Characteristics, Uses and Abuses. Enrique Touceda. (Abstract of paper read before the Pittsburgh Ry. Club.) (47) June 30.

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Modern Blast Furnace Erected in 85 Days for Cambria Steel Company.* (116) July; (20) June.
How Tuyeres Indicate Furnace Conditions (in Metallurgy).* Wallace G. Imhoff. (116) July.
Service Data on the Brown Furnace Top.* K. L. Landgrebe. (116) Serial beginning July.
Some Problems in Physical Metallurgy at the Bureau of Standards. George K. Burgess. (3) July.
The Aladdin Story of Aluminum.* James Preston Porter. (108) July.
Use of Oils in Flotation. Herbert A. Megraw. (16) July 1.
Froths Formed by Flotation Oils.* William A. Mueller. (16) July 1.
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Bunker Hill and Sullivan Milling Data.* R. S. Handy. (16) July 1.
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Crystallization in Cold-Worked Steel.* Ralph H. Sherry. (Abstract of paper read before the Soc. of Automobile Engrs.) (20) July 13.
The Metallurgy of the Rarer Metals. J. W. Richards. (Paper read before the Am. Inst. of Chemical Engrs.) (82) July 15.
Plant Construction of the New Cornelia Copper Co., Arizona. W. A. Scott. (82) July 15.
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Operating a Small Copper Blast Furnace.* A. Bregman. (16) July 22.
L'Ecrouissage du Cuivre. Léon Guillet. (93) Sept., 1915.
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Contribution à l'Etude du Procédé Bessemer. D. K. Tchernoff. (93) Oct., 1915.
Sur l'Obtention Directe de Fer et d'Acier Fondu au Haut Fourneau. D. K. Tchernoff. (93) Oct., 1915.
Sur la Structure des Alliages Cuivre-Zinc et Cuivre-Etain.* Witold Broniewski. (93) Nov., 1915.
Le Décapage au Bisulfate de Soude.* H. Le Chatelier et B. Bogitch. (93) Nov., 1915.
Ueber die Verwendung von Rohkohle im Hochofenbetrieb.* Fr. Lange. (50) April 20.

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Manufacturing British 8-In. Shells in 4½ Hours.* Fred H. Colvin. (72) Serial beginning May 4.
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The Military Rifle.* Douglas T. Hamilton. (From *Machinery.*) (19) May 20.
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The Making of Military Roads.* (From the *Illustrated News.*) (19) June 24.
Military Training Valuable and Valueless. Richard Stockton, Jr. (44) July.
Three River Crossings in the European War; Tactical; Technical Considerations.* Oberst Friedrich Immanuel. (100) July.
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With the 22d Corps of Engineers at Camp Whitman.* Robert K. Tomlin, Jr. (14) July 1.
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Design of Rolls for Making Steel Shrapnel Bars.* W. S. Standiford. (72) July 20; (108) June.
Sur l'Erosion des Canons d'Acier par les Gaz de la Poudre. D. K. Tchernoff. (93) Oct., 1915.

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Sur la Fabrication des Obus de Rupture.* D. K. Tchernoff. (93) Oct., 1915.
La Fabrication des Obus en Fonte.* Ch. Dantin. (33) May 27.

Mining.

Notes on the Specification of Iron and Steel Suitable for Colliery Use. W. Simons. (Paper read before the North Staffordshire Inst. of Min. and Mech. Engrs.) (106) Vol. 51, Pt. 2.
The Sinking and Equipment of a Circular Shaft. James Nisbet. (Paper read before the Min. Inst. of Scotland.) (106) Vol. 51, Pt. 2.
Carbon Dioxide as an Agent in Extinguishing Mine Fires, with Special Reference to Its Application at the Senghenydd Colliery.* Edgar C. Evans. (Paper read before the Manchester Geological and Min. Soc.) (106) Vol. 51, Pt. 2.
The Influence of Incombustible Substances on Coal-Dust Explosions. A. S. Blatchford. (Paper read before the North of England Inst. of Min. and Mech. Engrs.) (106) Vol. 51, Pt. 2.
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Electric Power in Slate Quarries.* G. K. Paton. (Abstract of paper read before the Liverpool Eng. Soc.) (26) Apr. 28; (73) June 30.
Colliery Pumping Plant in North Staffordshire.* (12) Apr. 28.
Firedamp Detector for Miners' Electric Safety Lamps.* T. J. Thomas. (57) Apr. 28.
Conditions of Winding: Report of Committee of the Am. Min. Congress. (From *Bulletin*, U. S. Bureau of Mines.) (57) Apr. 28.
Prospecting Before Dredging on Seward Peninsula, Alaska.* Corey C. Brayton. (103) Apr. 29.
Surficial Indications.* Frank H. Probert. (103) Serial beginning May 6.
Panel Room and Pillar Mining.* A. G. Horrock. (45) May 6.
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Gob Fires at Leycett Collieries.* W. G. Peasegood. (Paper read before the National Assoc. of Colliery Managers.) (22) May 12.
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Types of Arc and Incandescent Lights for Mine Locomotives.* P. S. Bailey. (82) May 13.
The Tale of the National Gold Mine a Latter Day Bonanza. Horace V. Winchell. (82) May 13.
A Plant for Thin-Seam Coal.* R. G. Read. (45) May 13.
The Tierney Tipple at Stone, Ky.* H. Reisser. (45) May 13.
Outside System of Electrical Shot-Firing. H. H. Clark, N. V. Breth and C. M. Means. (From *Technical Paper 108*, U. S. Bureau of Mines.) (57) May 19.
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Portable Mining Equipment for Prospects.* Louis A. Rehfuss and W. Clifford Rehfuss. (16) June 10.
An Underground Mine Stable.* Guy E. Greer. (45) June 10.
Gold Mining in the Judith Mountains, Montana.* O. W. Freeman. (103) June 10.
Fighting an Anthracite Mine Fire.* W. B. Richards. (45) June 10.
Mining at the Nevada Consolidated.* P. B. McDonald. (103) June 10.
Mine Air Analysis. W. H. McMillan. (Paper read before the National Assoc. of Colliery Managers.) (22) June 16.
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Stope Surveying at Mount Lyell.* G. F. Jakins and L. J. Coulter. (Paper read before the Australian Inst. of Min. Engrs.) (16) July 15.
Experiments in Relieving Strain Breaks in Quarries.* Oliver Bowles. (Abstract from *Bulletin 106*, Bureau of Mines.) (86) July 19.
Nomenclature of Mining Methods. George J. Young. (16) July 22.
Le Remblayage Hydraulique des Mines, Emploi du Sable de Dunes pour le Remblayage des Mines de Lens.* (33) June 17.

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Some Details Often Overlooked by Engineers. A. Stucki. (58) Feb.
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Effect of Atmospheric Pressure on the Candle Power of Various Flames.* E. B. Rosa, E. C. Crittenden and A. H. Taylor. (Paper read before the Illuminating Eng. Soc.) (66) Apr. 25.
The Forest Resources of Newfoundland. Daniel Morris. (29) Apr. 28.
Equitable Specifications and Contracts. Hillis F. Hackedorn. (55) May.
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The Nitration of Toluene. E. J. Hoffman. (105) May 1.
Humidity and Its Measurement. Kenneth G. Smith. (From the *Iowa Engineer.*) (64) May 2.
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Tar Products; Their Past and Future. J. Herbert Canning. (Paper read before the Wales and Monmouthshire District Institution of Gas Engrs. and Managers.) (66) May 30.
How to Study Factory Efficiency.* J. K. Mason. (9) June.
Cost Keeping the Basis of Prosperity. Harry Franklin Porter. (9) June.
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Sulphate of Ammonia and Benjol.* D. Bagley. (22) June 2.
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Wood Waste and Other Pulpwoods Used in 1914 by United States Mills. Henry E. Surface. (105) June 15.
The Densitometer.* G. A. Shakespear. (11) June 16.
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Theory of Public Utility Franchises. George McLean. (Paper read before the Iowa District Gas Assoc.) (24) June 26.
The Executive and the Modern Organization. Dwight T. Farnham. (9) Serial beginning July.
Industrial Preparedness and the Engineer. William L. Saunders. (9) July.
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Ditching and Digging Pole Holes with Dynamite. Thomas M. Knight. (86) July 19.
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La Réëducation Professionnelle des Blessés et des Mutiles de la Guerre.* Jules Amar. (93) Oct., 1915.
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California's Bituminous Carpeted Concrete Roads Show Durability in Service, Report States. (14) May 6.
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Methods and Costs of Concrete Road Maintenance in Ohio. A. H. Hinkle. (86) May 10.
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Lessons in Road Maintenance from New York State. T. M. Ripley. (13) May 11.
Road and Bridge Construction and Maintenance in the Province of Nova Scotia.* (Abstract from Report of the Highways Div.) (96) May 11.
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The Non-Such Tar Painting Outfit.* (104) May 12.
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Uniformity Required in Pavement Foundations. W. W. Crosby. (Abstract from paper read before the Canadian and Inter. Road Congress.) (86) May 17.
Artificial Foundations for Pavements. W. W. Crosby. (Paper read before the Canadian and Inter. Road Congress.) (86) May 17.
Increasing Water Works Efficiency Under City Manager Government. (86) May 17.
System of Road Working in Warren County, Kentucky. M. H. Crump. (86) May 17.
Retaining Walls on Bathurst Street Hill, Toronto.* S. G. Talman. (96) May 18.
Aprons Reduce Flood Damage to Road Shoulders.* George E. Schaefer. (14) May 20.
Asphalt Flush Coat Seals Porous Road Surface. (14) May 20.
The Easton-Allentown Concrete Road; an Exceptional Example of Modern Road Engineering.* Wm. D. Uhler. (Paper read before the Am. Road Builders' Assoc.) (86) May 24.
Comparative Values of Various Approved Forms of Street Pavements and Roads. E. M. Re Qua. (86) May 24.
Organization as Influenced by Plant of Concreting Gangs for Road Construction.* Halbert P. Gillette. (Report of Committee of National Conference on Concrete Road Building.) (86) May 24.
Method and Cost of Bitulithic Paving, Pierce Co., Wash.* David H. White. (13) May 25.
Width and Allocation of Space in Roads. F. Longstreth Thompson. (Paper read before the Town Planning Inst.) (96) May 25.
Standard Nomenclature and Specifications for Tar and Pitch for Road Purposes. Engineering Standards Committee. (22) May 26.
The Park-Development Problems in the Hard-Coal Region.* Karl B. Lohman. (45) May 27.
Concrete Paving a Remedy for Unsightly Alleys.* John C. Hiteshew. (14) May 27.
Favors Mill-Bent Angle-Iron as Concrete Road Screed. (14) May 27.
Highway Construction in Washington by Convict Labor. (86) May 31.
Practice of Peoria Ry. Co., Peoria, Ill., for Paving Street Railway Tracks. R. F. Palmblade. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (86) May 31.
Highway Problems of the State of Pennsylvania. William D. Uhler. (3) June.
The Quincy Shore Boulevard of the Boston Metropolitan Park Commission.* (60) June.
Building Concrete Roads. Homer P. Cumings. (Paper read before the Ohio Eng. Soc.) (60) June.
Prompt Snow Removal in Philadelphia, Pa.* William H. Connell. (60) June.
Minimum Tire Widths for Good Roads. Harold L. Hock. (36) June.
Chicago has New Shop Plant for All Public Works.* C. C. Sauer. (13) June 1.
Practical Maintenance of Road Plants.* M. E. Fafard. (Abstract of paper read before the Third Canadian and Inter. Good Roads Congress.) (96) June 1.

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Brick and Asphalt Paving by Day Labor. G. C. Brehm. (13) June 1.
Rolling Important for Asphalt-Gravel Roads. A. P. Rice. (Abstract of paper read before the Mass. Highway Comm.) (14) June 3.
Asphaltic Concrete Pavements. D. T. Pierce. (17) June 3.
Waterbound Macadam Tarsurfaced Stands Heavy Traffic. (14) June 3.
The Regeneration of Powdertown.* (76) June 6.
Planning the Industrial Town of Iroquois Falls, Ontario.* A. P. Melton. (86) June 7.
Standard Units for Comparing Municipal Improvements. A. Prescott Folwell. (Paper read before the Annual Conference of Mayors of the State of New York.) (86) June 7.
Annual Report on Highway Improvement in Ontario. (96) June 8.
City Paving Compared with Contract Work. Adolph F. Meyer. (Abstract from *Bulletin*, Civ. Engrs. Soc. of St. Paul.) (13) June 8.
Public Works Accounting for Villages and Towns.* Charles A. Holden. (13) June 8.
Road Culverts in Quebec Province. Alexander Fraser. (Abstract of paper read before the Inter. Road Congress.) (96) June 8.
Surrey Bituminous Road Surfacing Scheme, Materials, Methods and Details of Cost. (104) June 9.
Good Roads and the Automobile.* A. M. Jungmann. (19) June 10.
City Makes Money by Purchasing Plant and Laying its Own Asphalt Paving.* Clarence E. Ridley. (14) June 10.
John Nolen Says City Planning is for Small Cities as well as for Large Ones. (Abstract of paper read before the National Conference on City Planning.) (14) June 10.
Hydrated Lime in Concrete Pavements.* G. Cameron Parker. (86) June 15.
Maintaining the Washington-Atlanta Highway.* (14) June 17.
Pour Filler over Blocks in Granite Pavement. (14) June 17.
Construction Features of an Asphaltic Macadam Road in Massachusetts.* E. H. Townsend. (Paper read before the Mass. Highway Comm.) (86) June 21.
Modern Brick Road Construction. H. E. Bilger. (Paper read before the Conference on Highway Eng. at Kansas State Agricultural Coll.) (86) June 21.
Road Maintenance, Materials and Methods. William H. Connell. (Paper read before the Canadian and Inter. Good Roads Congress.) (96) June 22.
Automobiles, Motor Trucks and City Planning. Nelson P. Lewis. (Abstract of paper read before the City Planning Conference.) (13) June 22.
County Marks its Roads with Simple Signs; Main Plate Carried by 2-Inch Pipe Anchored in Post Hole by Grout and Rock Filling.* (14) June 24.
Simplicity the Keynote of Oregon's Cost-Keeping System.* G. Ed. Ross. (14) June 24.
Making Roads and Men.* O. R. Geyer. (19) June 24.
New Pavement Construction on Queensboro Bridge, New York City. (86) June 28.
Gravel Roads Constructed in Northwestern Michigan. L. H. Neilsen. (Paper read before the Battle Creek Highway Convention.) (86) June 28.
San Francisco's Civic Center.* (13) June 29.
Old Gravel and Macadam for Brick Pavement Foundation. H. E. Bilger. (Abstract from *Illinois Highways*.) (13) June 29.
Mysteries of Concrete Road Construction. W. H. Reed. (60) July.
Bitulithic Pavement Laid Over Old Gravel Road.* David H. White. (14) July 1.
The Columbia River Highway.* (19) July 1.
The Clayton County, Iowa, Patrol System for Maintenance of Dirt Roads. Edward B. Tourtellot. (From *Service Bulletin*, Iowa Highway Comm.) (86) July 5; (14) May 13.
Methods and Cost of Treating Old Macadam Streets in Milwaukee, Wis., with Asphaltic Oil.* Stanley E. Bates. (86) July 5.
Cutting Haulage Cost in Road Work to Seven Cents Per Ton-Mile. G. N. Lamb. (86) July 5.
Comparative Cost of Various Types of Pavement.* Eugene W. Stern. (Paper read before the Second National Conference on Concrete Road Bldg.) (86) July 5.
Organization and Output of a Gang Laying Concrete Base for Asphalt Pavement.* W. D. Jones. (86) July 5.
Asphalt Macadam Construction in Lake County, Indiana. (86) July 5.
Portable Washing Plant for Preparing Aggregates for Concrete Road Construction. H. Colin Campbell. (86) July 5.
Some Comparative Tests of Wire-Cut-Lug and Repressed Paving Brick. Wm. A. Goss. (86) July 5.
Miscellaneous Street Signs.* (13) July 6.
Excess Condemnation and City Planning.* Charles K. Mohler. (13) July 6.
Brick Pavement Carries 4 492 Vehicles a Day. (14) July 8.
Steam Shovel Removes and Loads Old Pavement and Foundation.* (14) July 8.
Changes in New Specifications for Paving in St. Louis. (13) July 13.
Hamilton Entrance of Toronto-Hamilton Highway.* E. Howard Darling. (96) July 13.

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Motor Truck Lessens Cost of Maintaining Gravel Roads in Alabama.* Thomas H. Edwards. (14) July 15.
Harrowing Highy Important in Gravel Roads. H. E. Bilger. (14) July 15.
Concrete Road Develops Three Cracks in a Year. (14) July 15.
Prorating Paving Costs Among Property Owners.* H. M. Talbott. (13) July 16.
Cost Analysis of Asphaltic-Concrete Pavements. (13) July 20.
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Bebauungsplan für ein städtisches Gelände an der Uellendahler Strasse und Kohlstrasse in Elberfeld im Hinblick auf seinen Werdegang.* Voss. (39) Serial beginning Mar. 5.
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Test of Locomotives.* D. R. MacBain. (61) Apr. 18
Concealed Damage. W. H. Streeter. (Paper read before the United Yard Masters' Assoc.) (23) Apr. 21.
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Commercial Motor Vehicles for Railway and Industrial Purposes. (23) Serial beginning Apr. 28.
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Handling a Big Engine Terminal. Paul A. Schenck. (25) May.
The Sanitation of Railway Cars. Thomas R. Crowder. (65) May.
Northern Pacific Express Cars.* (25) May.
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The Cause of Slid Flat Wheels.* Walter V. Turner. (Abstract of paper read before the St. Louis Ry. Club.) (25) May.
Test of the Young Valve and Valve Gear.* (25) May.
The Use of Continuous Current for Terminal and Trunk-Line Electrification.* Norman Wilson Storer. (77) May 1.
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The Garratt Locomotive.* H. W. Dearberg. (Paper read before the Institution of Locomotive Engrs.) (23) May 5.
New 4-6-0 Type Locomotives, London & Northwestern Railway.* (23) May 5.
Concrete Work on the Arizona Division of the Santa Fe.* (23) May 5.
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How French Hospital Trains Help to Save the Wounded. (23) May 5.
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West Side Improvement Plans of New York Central Railroad in New York Filed.* (14) May 6.
The Government Railroad in Alaska, What Two Years and Limited Funds Have Accomplished.* Thomas Riggs, Jr. (14) May 6.
Routing Systems in the Small Shop.* H. D. Wolcomb. (18) May 6.
Results Obtained with Roller Bearings on Interurban Cars.* W. B. Voth and A. C. Metcalfe. (17) May 6.
Caboose Cars for the Nashville, Chattanooga & St. Louis Ry.* (18) May 6.
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Lateral Stresses on Rails in Curves.* George L. Fowler. (23) May 12.
Long Freight Trains and Railway Accidents; a Study of the Relation Between Train Length and Accidents to Trains and Casualties to Persons. (From *Bulletin*, Bureau of Ry. Economics.) (15) May 12.
Locomotive Impact Tests on the Burlington.* C. B. Young. (15) May 12; (25) June.
Slack Action in Long Passenger Trains. (Paper read before the Air Brake Assoc.) (15) May 12; (25) June.

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Is the Ton-Mile the Proper Basis for Allocating Railroad Operating Costs? Paul M. La Bach. (14) May 13.
Federal Regulation, Including the Labor Problem. Daniel Willard. (Paper read before the Am. Newspaper Publishers' Assoc.) (18) May 13.
Signaling in the Public Service Terminal.* J. W. Brown. (17) May 13.
The Function of Federal Valuation in Rate Making.* C. C. James. (Paper read before the Railroad Men's Improvement Assoc. of New York.) (18) May 13.
New 0-6-2 Type Tank Engines, Glasgow & South Western Railway.* (23) May 19.
The Strength and Wear of Locomotive Tires. E. L. Ahrons. (Paper read before the Institution of Locomotive Engrs.) (12) Serial beginning May 19.
Buildings and Structures. (Report of Committee of the Inter. Ry. Fuel Assoc.) (15) May 19.
Report of Committee of the Inter. Ry. Fuel Assoc. on Powdered Fuel.* (15) May 19.
An Operating Study of the Rock Island.* (15) May 19.
The Pacific Electric Railway.* (23) May 19.
Report on Amherst Collision. (From Report of the Interstate Commerce Comm.) (15) May 19.
L. & N. W. R. Ambulance Train Vehicles for Service on the Continent.* (23) May 19.
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Report of Committee on Lumber of the Inter. Ry. Fuel Assoc. (15) May 19; (25) June.
The Eymon Continuous Crossing.* (18) May 20.
Rail Weights Reduced to Lengths, and *Vice Versa,* Tables Compiled for Converting Linear Feet of Eighteen Sections into Tonnages, and Tonnages into Track Miles. James G. Wishart. (14) May 20.
The Difficulties of Railroad Maintenance in Alaska.* Kirk McFarlin. (46) May 20.
The Effectiveness of Coasting Recorders in Reducing Power Consumption and Operating Costs. V. W. Berry. (17) May 20.
Traffic Development on the Scranton & Binghamton R. R.* (17) May 20.
The Railroad Fuel Problem, Past and Present. S. M. Felton. (Paper read before the Inter. Ry. Fuel Assoc.) (18) May 20.
Care of Locomotives with Relation to Fuel Economy. A. N. Willsie. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 26; (25) June.
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Fuel Economy and the Transportation Officer. W. H. Averell. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 26; (18) May 20.
Railways in a System of National Defense. W. L. Park. (Paper read before the Inter. Assoc. of Ry. Special Agents and Police.) (15) May 26.
Economics of Crossties Reduced to Figures. (14) May 27.
Prospective Development and Earnings Affect the Value of a Railroad.* R. B. Shepard, Jr. (14) May 27.
The Ureco Refrigerator Brine Tank Valve (for Cans).* (18) May 27; (25) June.
Economy Pony and Trailing Trucks for Locomotives.* (18) May 27.
Some Notes on Signal Maintenance. A. G. Shaver. (18) May 27.
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Terminal Cleaning of Passenger Cars. J. E. Ross. (25) June.
Dismantling of Cars. J. W. Gerber. (Paper read before the Ry. Storekeepers' Assoc.) (25) June.
The Safe Lock Switch Machine.* (87) June.
Functions of a Railroad Fuel Inspector. Eugene McAuliffe. (Paper read before the Inter. Ry. Fuel Assoc.) (15) May 19; (18) May 20; (25) June.
The Human Fireman. Ralph Bradley. (Paper read before the Inter. Ry. Fuel Assoc.) (25) June; (18) July 8.
A New Track Fastening.* (87) June.
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Rogers Pass Soft-Ground Work.* J. G. Sullivan. (13) June 1.
Garratt Locomotive for Brazil.* (23) June 2.
The Operation of the Railroads in New England. (Abstract of paper read before the New England R. R. Club.) (15) June 2.
Rail Manufacture. J. S. Unger. (Paper read before the Am. Iron and Steel Inst.) (15) June 2; (116) June; (18) July 15.
Mikado Type Locomotives for the Atchison, Topeka & Santa Fe Ry.* (18) June 3.
Method of Handling Repairs to Foreign Cars and Billing for Same.* E. S. Way (Paper read before the Ry. Club of Pittsburgh.) (18) June 3.
Treatment of Feed Water for Locomotive Boilers. L. F. Wilson. (Paper read before the Cincinnati Ry. Club.) (18) June 3.
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Power Brakes for Goods Trains.* (23) June 9.
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L. C. L. Freight Handling Methods at Silvis Transfer, Ill.* (15) June 9.
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Application of Ball Bearings to Railway Car Journals. O. Bruenauer. (Abstract of paper read before the Illinois Elec. Rys. Assoc.) (17) June 10.
New Interurban and Work Cars for the K. C. C. C. & St. J. Ry.* J. N. Spellman. (17) June 10.
Baltimore & Ohio Adds Second Dynamometer to Car; Diaphragm Type Instrument Indicates Both Pulling and Buffing Forces, and is Sensitive to Small Variations. (14) June 10.
Operation on the Baltimore & Ohio Electrification.* (17) June 10.
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Report on Standardization of Screw Threads.* F. O. Wells. (Paper read before the Master Mechanics' Assoc.) (15) June 20; (18) June 24.
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Rebuilding Small Passenger Stations.* H. F. Haag. (18) July.
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Testing and Adjusting Track Scales by the Graphical Method.* C. A. Briggs (Paper read before the National Scale Men's Assoc.) (18) July 15.
A Rapid and Accurate Method of Cross-Sectioning Tunnels.* T. H. Robertson. (18) July 15.
Advances Allowed in Eastern Canadian Freight Rates. (18) July 15.
Are Old Rails Worth Conserving. John Reinehr. (Paper read before the Ry. Storekeepers' Assoc.) (18) July 15; (87) July.
Railroads Will Demand Central Station Energy.* Frederic Nicholas. (27) July 15.
St. Paul is Doing Intricate Track-Elevation Work in Chicago with Company Forces.* (14) July 15.
Hydraulic Excavation of a Large Cut in Cleveland, Ohio, Grade Crossing Elimination. C. E. Drayer. (86) July 19.
Railway Improvements at Clinton, Iowa. (13) July 20.
Railway Regulation Causes Locomotor Ataxia. Frank Trumbull. (Paper read before the National Hay Assoc.) (15) July 21.
Lift Bridges at a Freight Platform.* (15) July 21.
Position Light Signals on the Pennsylvania. (15) July 21.
Car for the Transportation of Live Fish.* (15) July 21.
Pacific Type Locomotives for the Reading.* (15) July 21.
L'Eclairage Electrique des Trains.* (33) Feb. 12.
L'Excavation du Tunnel du Mont Royal à Montréal (Canada).* F. Hofer. (33) Apr. 29.
Chariot-Transbordeur à Commande Hydro-Electrique de la Gare de Moor Street, à Birmingham (Angleterre).* (33) May 6.
L'Equippement des Lignes Aériennes Triphasées des Chemins de Fer Electriques italiens.* Carlo Maurilio Lerici. (33) May 13.
L'Application de la Condensation sur les Locomotives à Vapeur.* J. Carlier. (33) June 3.
La Ligne de Jonction Athènes-Salonique entre Papapouli et Plati.* (33) June 10.

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Chauffage au Poussier de Tourbe d'une, Locomotive à Marchandises de l'Etat suédois.* (33) June 17.
Comparaison des Spécifications en Vigeur pour la Fourniture des Rails.* A. Goupil. (33) July 1.
Neuere Studien über die Schwankungen des Kraftbedarfs der elektrischen Zugförderung.* W. Kummer. (107) Serial beginning Apr. 22.
Einige Erfahrungen im Lehnenbau an der Südrampe der Lötschbergbahn.* C. Andreae. (107) Serial beginning May 6.
Der elektrische Betrieb auf den Linien des Engadin.* H. Haueter. (107) May 13.
Die Begrenzung des lichten Raumes und der Fahrzeuge der schweizer. Normalspurbahnen.* R. Winkler. (107) June 3.

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The Construction of the Dorchester Tunnels Under Fort Point Channel.* A. A. Cohill. (109) May.
Power Developments for Urban Transportation.* Clifton W. Wilder. (9) May.
Rapid Transit Work in 1915, New York City.* D. A. Sealey. (13) May 4.
Special Track Layouts Made Interchangeable.* Burr S. Watters. (17) May 6.
Latest Connecticut City Cars.* (17) May 6.
Rail Joints. R. H. Findley. (Paper read before the Iowa Gas, Electric Light, Street and Interurban Ry. Assoc.) (17) May 13.
The Building and Financing of Subways. (Paper read before the Am. Elec. Ry. Assoc.) (96) May 18.
One-Man, Light-Weight Cars. W. E. Moore. (Paper read before the Pennsylvania Street Ry. Assoc.) (17) May 20.
Des Moines Front and Center-Door Cars.* (17) May 20.
Stepless Double-Deck Car Introduced in Vienna.* Ludwig Spängler. (17) June 3.
Equipment Records on the Binghamton Railway.* (17) June 3.
Some Problems of the Electric Railway Industry. F. W. Doolittle. (Paper read before the New England Street Ry. Club.) (17) June 3.
A Method of Excavating Deep Cuts to Neat Lines (in Subway Construction).* (86) June 7.
Copper-Zone System Sustained, Connecticut Commission in Groton & Stonington Street Railway Case Says New System is Improvement Over Old Nickel-Zone System. (17) June 10.
Design and Construction of the Harlem River Four-Track Subway Tunnel. (86) June 14.
Energy Saved with Roller Bearings. H. A. Johnson. (Paper read before the Illinois Elec. Rys. Assoc.) (17) June 17.
Roller Bearings for Railway Use. Raymond H. Carhart. (Paper read before the Illinois Elec. Rys. Assoc.) (17) June 17.
New Route Signs for Denver.* (17) June 17.
Storeroom Systems. A. Schwarz. (Abstract of paper read before the Central Elec. Ry. Accountants' Assoc.) (17) June 24.
Prospects Poor for Seattle Municipal Lines. (17) June 24.
Power Generation for Electric Railways.* Henry G. Stott. (Abstract of paper read before the Am. Elec. Ry. Assoc.) (17) June 24.
A New Low-Floor End-Entrance Car.* (17) June 24.
B. J. Arnold Reports on Bay State Street Railway.* (17) July 1.
Investment per Revenue Passenger and Density of Traffic.* D. J. McGrath. (17) July 8.
Electric-Welded Joints Installed at Low Cost (on Indianapolis Railways).* R. J. Smith. (17) July 8.
Single-Truck, Arch-Roof Cars of the United Traction Company, Albany.* (17) July 8.
Concreting Track in Fort Smith, Ark.* (17) July 15.
Special Details Are Used in the Design of Steel Elevated Structures in Brooklyn.* (14) July 15.
Reinforcing Tubular Poles Internally.* L. L. Foster. (17) July 15.
Car-Lighting Improvements and Costs on the Los Angeles Railway.* J. L. Clarke. (17) July 15.
Inexpensive Excavation by Cleveland Railway Co. (86) July 19.
Die elektrischen Stadtschnellbahnen der Vereinigten Staaten von Nordamerika. F. Musil. (102) Mar. 1.

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Intensive Street Cleaning Methods.* Richard T. Fox. (4) Mar.
The Extent to Which Sewage Can Be Purified by Practicable Methods of Artificial Treatment Now in Use. Harrison P. Eddy. (58) Apr.
The Duties of a Municipal Engineer and Surveyor in Connection with Factories and Workshops. Frederick Sadler. (114) No. 11, Apr.
Sewerage in the Doncaster Rural District.* Walter R. Crabtree. (114) No. 12, Apr.
Sewage Treatment Plant.* C. Arthur Poole. (60) May.

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Disposal of Municipal Refuse. Hiram Phillips. (115) May.
The Transmissibility of Diseases, and the Public Health. Alexander Crever Abbott. (3) May.
Results of First Year's Experiments with Small Sewage Treatment Plants by U. S. Public Health Service. Leslie C. Frank. (86) May 3.
Land Drainage Project in Northern Minnesota.* (13) May 4.
Imhoff Tank and Dunbar Filters at Ennis, Tex.* (13) May 4.
Reinsch-Wurl Sewage Screen, Long Beach, Calif.* E. A. Rowe. (13) May 4.
Miners' Wash and Change Houses.* Joseph H. White. (From *Technical Paper 116*, U. S. Bureau of Mines.) (57) May 5.
Warm Air Heating in a Northern City.* (101) May 5.
Small Sewage Pumping Station for Park Site, Centrifugal Pumps, in Duplicate, Serve District of 2 000 Population in West Chester, Pa., Control is Automatic.* W. De Witt Vosbury. (14) May 6.
Grease and Fertilizer Base from Boston Sewage. Robert Spurr Weston. (Abstract from *Journal*, Am. Public Health Assoc.) (13) May 11.
Steel Aqueduct for Sewer.* (13) May 11.
Scarcity of Steel Results in Plain Concrete for Sewers.* (13) May 11.
Torquay Medical and Swimming Baths.* (104) May 12.
Furnace Installation Ordinance, Columbus, Ohio. (101) May 12.
Plumbing and Heating Details of Plunges.* (101) May 12.
Electric Drive Replaces Steam for Drainage Pumps.* E. J. Hegerty. (14) May 13.
Making Farm Drainage a Matter of Public Record.* John W. Anderson. (Paper read before the Iowa Clay Products Mfrs.' Assoc.) (76) Serial beginning May 16.
Time Temperature Curves During the Salting of Some Oil-Fired Sewer-Pipe Kilns.* F. H. Riddle and A. L. Gladding. (Paper read before the Am. Ceramic Soc.) (76) May 16.
Vitrified Clay Segment Blocks in Sewer Construction. J. M. Egan, Jr. (Paper read before the Illinois Soc. of Engrs. and Surveyors.) (76) May 16.
Activated-Sludge Process on Stockyards Sewage. Arthur Lederer. (13) May 18.
Tests of Effect of Method of Bending Upon the Supporting Strength of Drain Tile and Sewer Pipe.* N. J. Schlick. (Paper read before the Iowa Drainage Assoc.) (91) May 18.
Remodeled Steam Plant in Southern Hotel.* L. A. J. (101) May 19.
Corrugated Culvert Pipes Tested Under a Sand Bed.* George L. Fowler. (17) May 20.
Sewage Screening and Sludge Burning Plant Prevent Sea Shore Nuisances at Long Beach, Cal.* (14) May 20.
Experimental Studies of Strawboard Waste Purification. Harry B. Hommon. (Paper read before the Indiana San. and Water Supply Assoc.) (86) May 24.
Some Important Details of Land Drainage Work.* (13) May 25.
Activated Sludge Experiments at Milwaukee. R. O. Wynne-Roberts. (96) May 25.
Schemes for Heating Small Assembly Hall.* (101) May 26.
Sewage and Refuse Disposal at Malden and Coombe, Surrey. R. H. Jeffes. (Paper read before the Lower Thames Valley District Surveyors' Assoc.) (104) May 26 .
The Typhoid Toll.* George A. Johnson. (59) June.
The Latest Method of Sewage Treatment.* Edward Bartow. (59) June.
Mosquito Extermination in Panama and New Jersey.* Harold I. Eaton. (109) June.
Sewage Disposal by the Activated Sludge Process. T. Chalkley Hatton. (Abstract of paper read before the Ontario Health Officers' Assoc.) (96) June 1.
Traveling Sewage-Distributor Changes, Springfield, Mo.* Alexander Potter. (13) June 1.
Modern Plumbing for the Country Home.* A. H. D. (101) June 2.
Water Heater Systems.* E. S. Stack. (24) June 5.
Storing and Pumping Sewage, Manchester, Mass.* Charles W. Sherman. (13) June 8.
State-Wide Clean-Up of Labor Camps in California.* J. J. Rosenthal. (13) June 8.
Plumbing Equipment in Country High School.* (101) June 9.
Report of the Ventilation Research Committee of the Institution of Gas Engineers.* (66) June 13.
Sewage Treatment Works for Cities on Boundary Waters. Earl B. Phelps. (86) June 14.
Sewage Treatment Study for Niagara Falls, Ontario.* H. S. Phillips. (86) June 14.
Positive Fresh Warm-Air System for School.* (101) June 16.
Hot Water System in a Small Farmhouse. Poarco. (101) June 16.
Conservation of Operating Head Controls Design of Oaklyn (N. J.). Sewage Plant.* W. De Witt Vosbury. (14) June 17.
A New Dry-House. R. E. Tremoureux. (103) June 17.

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Purification of the Wastes from the Finishing of Woolen Goods. H. R. Croburst and A. D. Weston. (86) June 21.
Windsor District Sewage Disposal.* H. C. McRae. (Abstract from Report to the Inter. Joint Comm.) (96) June 22.
Grit Chamber and Pump Station, Albany Sewage-Works.* John H. Gregory. (13) Serial beginning June 22.
Urgent Need of Public Comfort Stations. J. J. Cosgrove. (Paper read before the Eastern Supply Assoc.) (101) June 23.
Equipment of Camps in Maine Woods.* (101) June 23.
Treharris Pit-Head Baths.* (57) June 23.
Six-Mile Sewer Extension Has Sinuous Course.* (14) June 24.
Mammoth Electric Draglines Dig Diversion Channels and Construct Levees.* (14) June 24.
The Proper Ratio of Economy Coils. Walter J. Kline. (Paper read before the National District Heating Assoc.) (64) June 27.
Low Cost Comfort Stations in Indiana Parks.* (101) June 30.
Methods Adopted for Heating a Town.* (101) Serial beginning June 30.
Direct Heating in Store and Lodge Building.* Charles L. Hubbard. (101) June 30.
The Element of Chance in Sanitation.* George C. Whipple. (3) July.
Central Station Steam Heating by Miles City, Montana, Municipal Plant. G. C. Pruett. (60) July.
Steam Requirements for Power and Heating. Charles L. Hubbard. (9) July.
Modern Air Facts Relating to Air and Ventilation in Relation to Health. John F. Norton. (19) July 1.
Sanitary Conveniences for Soldiers.* (101) July 7.
Installation of Driving Equipment for Fans. H. Bard. (101) July 7.
Cleveland Street Railway Flushes City Streets; Car with 4 488-Gallon Tank Cleans 4 850 Feet of One Side of Street in 12 Minutes with One Filling of Tank.* H. C. Ebeling. (14) July 8; (17) July 8.
Misuse of Drainage Systems as Sanitary Sewers. Lafayette Higgins. (From the *Iowa Engineer.*) (19) July 8.
Steel Wall Forms for Imhoff Tank Construction at Columbus Sewage Treatment Plant.* (86) July 12.
Final Report on Elmhurst Disposal Plant. (13) July 13.
Amherstberg, Ont., Sewage Disposal. H. C. McRae. (Abstract from Report to the Inter. Joint Comm.) (96) July 13.
Kansas Experience in Running Small Sewage-Works. F. M. Veatch. (13) July 13.
Sewage-Testing Station Report Limits Processes. (14) July 15.
Gas Would Supply Temperature Necessary to Keep Air in Factories Ventilated by the Natural System, Within Permissable Limits. (24) July 17.
Land Drainage Project in Florida. (86) July 19.
Gantry Cranes Work on Sewer at Salt Lake City.* (13) July 20.
Air-Diffuser Experiences with Activated Sludge Tanks. (13) July 20.
Vapor Heating Systems and Equipment.* Charles A. Fuller. (101) Serial beginning July 21.
Arbitration by Engineers Saves Time and Money in Sewer-Valuation Case. Farley Gannett. (14) July 22.
Separate Sludge Digestion Improves Imhoff-Tank Operation by Keeping Sewage Fresh.* Karl Imhoff. (14) July 22.
La Construction et l'Organisation des Camps d'Internés belges en Hollande; Organisation de l'Enseignement dans ces Camps.* C. Lemaire. (33) July 1.
Die Sendric-Heiz- und Kühlapparate.* M. Hottinger. (107) June 3.

Structural.

Pit-Timber and Its Preservation. Percy Groom. (Paper read before the Midland Inst. of Min. Civ. and Mech. Engrs.) (106) Vol. 51, Pt. 2.
The Web Strength of I-Beams and Girders.* H. F. Moore. (4) Mar.
Wire and Wire Rope.* (98) Apr.
Practical Applications of Statically Inderterminate Constructions.* W. T. Holtappel. (2) Apr.
New and Cheap Building Materials for Cottages. H. L. Paterson. (Paper read before the National Congress on Home Planning After the War.) (104) Apr. 28.
The Mathematical Theory of the Elastic Arch. Willis Whited. (58) May.
The Practical Chemistry and Modern Manufacture of Portland Cement. Geo. P. Diekmann. (55) May.
Effect of Rust on the Rate of Corrosion. James Aston. (Paper read before the Am. Electro-Chemical Soc.) (62) May.
Slide Rules for Reinforced Concrete Design.* E. F. Rockwood. (109) May.
On Deformation Limit of Plastic Materials, Limiting the Blame for Cracking and Fracturing of Steel Under Rolling and Forging, Showing the Mechanical Factors Concerned in the Disturbance of Steel Structures.* (116) May.

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How to Select Industrial Steels. Arthur E. Paige. (9) May.
A Bargain in Homes. George W. Ritchie. (Paper read before the Am. Face Brick Assoc.) (76) May 2.
Heavy Concrete Beams Used in Rebuilding a Theater.* Layton F. Smith. (13) May 4.
Piledriving Details on the Yolo Bypass Trestle.* (13) May 4.
Cornice Runways for Swinging Scaffolds from Buildings.* (13) May 4.
The Corrosion of Metals. William E. Gibbs, Richard H. Smith and Guy D. Bengough. (Report to the Institute of Metals.) (47) May 5.
Physical and Mechanical Factors in Corrosion. Cecil H. Desch. (Paper read before the Faraday Soc.) (19) May 6.
Warehouse Crane Runways Carried on Wall Brackets, New Orleans Cotton Buildings Designed with Reinforced Concrete Walls to Resist Heavy Lateral Pressure and Carry Crane Loads.* (14) May 6.
Methods and Equipment Used in Constructing the Methodist Book Concern Building, Cincinnati, O.* (86) May 10.
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Testing of Chains. G. S. Taylor. (Abstract.) (47) May 12.
Test of Mushroom Flat Slab in Seattle Warehouse Shows High Local Stress.* D. E. Hooker. (14) May 13.
Riveted Joints Being Tested by Series of Simple and Accurate Mirror Extensometers.* (14) May 13.
An Ideal Nest Built with Hollow Tile.* (76) May 16.
Slag Portland Cement. B. J. Day. (Paper read before the Institution of Engrs. and Shipbuilders in Scotland.) (96) May 18.
Pressure of Wet Concrete on the Sides of Column Forms.* A. B. McDaniel and N. B. Garver. (13) May 18.
Building Concrete Lighthouse on Brandywine Shoal.* T. J. Rout. (13) May 18.
New Housing Development at Worcester.* W. E. Freeland. (20) May 18.
Wood Sheet Piles Jetted into Hard Pan with 400 Pounds Pressure.* K. D. MacLean. (14) May 20.
Methods Used in Re-Levelling a 200 000 Cu. Ft. Gas Holder. A. R. Schiller. (Paper read before the New England Assoc. of Gas Engrs.) (86) May 24.
Spacing of Shear Steel in Concrete Beams.* Robert S. Beard. (13) May 25.
Coating Steel at Grand Central Terminal with Cement Gun.* W. F. Jordan. (13) May 25.
How to Make Concrete Resist Action of Sea Water. W. Watters Pagon. (Abstract from *Journal*, Engrs. Club of Baltimore.) (14) May 27; (86) May 24.
Steel Skeleton of Bell Parkway Building Contains Heavy Portal Framing.* (14) May 27.
Penetration of Preservatives. Lowrie Smith. (87) June.
Portland Cement.* George A. Rankin. (3) June.
Building the Factory.* John T. Klaber. (9) June.
The Yale Bowl.* Thomas C. Atwood. (109) June.
The Painting of Iron and Steel.* James Scott. (21) June.
Government Reports Elaborate Concrete Strength Data. (Abstract, *Technologic Paper* No. 58, U. S. Bureau of Standards.) (13) June 1.
Steel Castings and Physical Properties.* Edwin F. Cone. (20) June 1.
The Relative Value of Different Fire Extinguishers.* (12) June 2.
New Hospital for the Illinois Central R. R. at Chicago.* (18) June 3.
New Trench-Excavation System.* (13) June 8.
Strength of Burnettized Timber to be Studied.* J. M. Barker. (13) June 8.
Two Buildings Carried Over a Railway Tunnel.* (13) June 8.
Large Reinforced-Concrete Mat Building-Foundation. (13) June 8.
The Cement Gun.* (11) June 9.
Simple Nickel Steels. Henry D. Hibbard. (From *Bulletin*, U. S. Bureau of Mines.) (47) Serial beginning June 9.
Heavy Vault Floor Framed into Existing Columns in Basement of Equitable Building.* (14) June 10.
Modern Ideas on Fireproof Construction.* S. M. Fechheimer. (82) June 10.
Compares Results of Tests on Three Types of Reinforced-Concrete Building Floors. D. E. Hooker. (Abstract of paper read before the Pacific Northwest Soc. of Engrs.) (14) June 10; (13) May 25.
Invar and Related Nickel Steels, Materials Having Peculiar Properties of Value for Scientific Instruments. (19) June 10.
The New Technology.* (72) June 15.
Tests Show Earth Pressure One-Half Hydrostatic.* (13) June 15.
Difficult Chimney Foundation Tested After Completion.* (13) June 15.
Reinforced-Concrete Stairway for Hillside Footway.* R. F. Odell. (13) June 15.
Lutes and Cements. S. S. Sadtler. (Abstract of paper read before the Am. Inst. of Chemical Engrs.) (47) June 16.

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The Critical Speeds of Shafts.* W. M. Wallace. (12) Serial beginning June 16.
Swinging Cargo Hoist Beams.* (14) June 17.
Artificial Seasoning of Timber. Ollison Craig. (Paper read before the Eng. Assoc. of the South.) (19) June 17.
Efficiency in Bridge and Building Work.* (Report of Committee of the Am. Ry. Bridge and Bldg. Assoc.) (18) June 17.
Largest Panel-Testing Furnace in this Country Constructed at Washington.* (14) June 17.
Test Compounds for Making Wood Fire Retardant. (14) June 17.
Mountain-Top Foundations Support Huge Telescope.* (14) June 17.
How to Build a Hollow Tile Silo.* (76) June 20.
Tremie Plant for Concreting Subaqueous Pedestals.* Kirby Smith. (13) June 22.
Long-Span Howe Trusses Fail.* (13) June 22.
Concrete Piles 100 Ft. Long.* (Abstract from *Concrete and Constructional Engineering.*) (13) June 22.
Test of Adhesion of Face Tile to Concrete Backing.* (13) June 22.
Bracket-Loads on Columns of Constant Cross-Section.* William Dunn. (11) June 23.
Specifications Cover Grade A Office Building; New Requirements of National Fire Protection Association Compared with Those for Standard Building. (14) June 24.
One Thousand Steel Specifications Reviewed. R. Fleming. (14) June 24.
Engineers and Architects Want Branded Timber. Frank D. Chase. (14) June 24.
Diagrams for the Design of Reinforced Concrete T-Beams. M. A. Drucker. (86) June 28.
Concrete Plant Handled on Four Freight Cars.* (13) June 29.
Malleable Iron, Its Characteristics, Uses and Abuses. Enrique Touceda. (Abstract of paper read before the Pittsburgh Ry. Club.) (47) June 30.
How Curing at Low Temperatures Affects Concrete.* A. B. McDaniel. (67) July.
Grape-Vine Posts of Concrete.* (67) July.
The Effect of Sulphur in Rivet Steel.* J. S. Unger. (116) July.
1 450-Ton Apartment House Moved 80 Feet on High Cribbing. (14) July 1.
Large Columns of Carbon and Alloy Steels Fail Near Yield Points of Material.* J. H. Griffith and J. G. Bragg. (14) July 1.
The Rusting of Iron and Some Methods for Its Protection. (From *Motorschiff und Motorboot.*) (19) July 1.
Load Test of Concrete Floor Cracked by Settlement.* J. H. Byrd. (13) July 6.
Japanning in Tumbling Barrels. T. P. Archer. (72) July 6.
Bond and Shear in Reinforced Footing Offsets.* Clifford Older. (13) July 6.
Weak Retaining Wall Saved by Anchored Buttresses.* (13) July 6.
Standard Test Specimens of Zinc-Bronze.* C. P. Karr and H. S. Rawdon. (*Bulletin,* U. S. Bureau of Standards.) (47) July 7.
Concrete Floors in the Home. (19) July 8.
The Nation's Research Laboratory, How the Bureau of Standards Is Helping Us to Do Without Europe.* (46) July 8.
Crystallization in Cold-Worked Steel.* Ralph H. Sherry. (Abstract of paper read before the Soc. of Automobile Engrs.) (20) July 13.
Details of Roof-Arch Collapse in Atlanta.* (13) July 13.
City Engineer Defines Quality of Lumber to Use. (14) July 15.
New Freezing and Thawing Apparatus Is Automatic. (14) July 15.
Test Concrete Cured Under Freezing Conditions.* (14) July 15.
The New Cement Specifications, the Changes Made and the Reasons Therefor. R. J. Wig. (14) July 15.
Heavy Wire Rope Tested at Bureau of Standards.* (14) July 15.
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Largest Dredging Caisson Sunk as Building Foundation.* (13) July 20.
Salvaging a Flooded Pumping Plant in California. Roy A. Silent. (13) July 20.
New Tests of Bolted Joints in Timber Framing.* H. D. Dewell. (13) July 20.
Subway Columns and Girders Designed to Support Future High Office Building.* (14) July 22.
Give Skin-Friction Data on Shaft Sinking in Chicago. (14) July 22.
Comfortable Houses Hold Men at Construction Camp.* (14) July 22.
Largest Bridge Caissons Rivaled by Timber Crib Sunk in Free Air in 34 Days.* (14) July 22.
Importance de l'Alésage des Trous de Rivets Dangereux Défaut de Certains Métaux. M. Mesnager. (43) July, 1914.
Les Arènes Athlétiques du Collège de New-York.* (33) May 6.
Das Problem des Industriebaues.* Bruno Bauer. (53) Serial beginning Apr. 14.
Die deutschen Vorschriften für Ausführung von Bauwerken aus Eisenbeton. (107) Apr. 22.

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Topographical.

Construction of an Unusual Relief Map for Los Angeles Aqueduct.* Burt C. Heinly. (86) May 24.
The Mathematics of Vertical Curves. Leonard C. Jordon. (86) June 7.
Autographic Cross-Sectioning by a New Instrument.* John Airey. (13) June 8.
Ingenious Special Devices for Tunnel Surveys.* (13) June 15.
Precise-Level Survey of the City of Portland, Ore.* W. P. Hardesty. (13) July 13.
Instrument Plots Profiles of River and Harbor Beds.* (14) July 22.
Surveying 1 000 Square Miles with the Camera.* (14) July 22.

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Improvements in the Art of Mechanical Filtration.* Thos. Fleming, Jr. (58) Jan.
Red Water and Suggested Remedies. Nicholas S. Hill, Jr. (8) Apr.
Water-Pressure Regulating Apparatus.* (11) Apr. 28.
The Solid Piston Humphrey Pump.* (12) Apr. 28.
Water Rights as a Liability. (From Report of R. R. Comm. of California.) (111) Apr. 29.
The Design and Test of a Large Reclamation Pumping Plant.* G. C. Noble. (55) May.
The Evolution of Low Lift Pumping Plants in the Gulf Coast Country.* W. B. Gregory. (55) May.
The Waldeck Reservoir in Germany.* Kenneth C. Grant. (98) May.
Relation of Water Power to Transportation. Lewis B. Stillwell. (42) May.
Prevention of Corrosion in Pipe. F. N. Speller. (Paper read before the Am. Soc. of Heating and Ventilating Engrs.) (25) May.
Water Power Development and the Food Problem. Allerton S. Cushman. (42) May.
Water Power and Defense. W. R. Whitney. (42) May.
Electrochemical Industries and Their Interest in the Development of Water Powers. Lawrence Addicks. (42) May.
The Water Power Situation, Including Its Financial Aspect. Gano Dunn. (42) May.
Winter Operation of Water Works at Miles City, Montana. G. C. Pruett. (60) May; (86) May 10.
The Reconstruction of the Municipal Water Works, Cambridge, Ohio. W. J. Sherman, M. Am. Soc. C. E. (109) May.
The Arrowrock Dam. H. A. Lawson. (115) May.
The Power Development. I. R. Edwards. (Paper read before the Am. Electro-chemical Soc.) (105) May 1.
Self-Cleaning Flume Screen.* (13) May 4.
Water-Supply of 500 000 Gal. Daily from River Springs.* (13) May 4.
Excavation for the Baldwin Reservoir, Cleveland.* (13) May 4.
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British Columbia Mining Hydro-Electric Plants.* Frank C. Perkins. (82) May 6.
Huge Circular Reservoir in Dubuque Protects Congested-Value Business District.* Dabney H. Maury. (14) May 6.
The Medlow Dam.* Percy Allan. (From the *Commonwealth Engineer.*) (111) May 6.
Filtration of Softened Water. F. F. Vater. (64) May 9.
Measuring the Water Used in Power-Plant Tests.* Charles G. Richardson. (64) May 9.
Experience in the Chlorination of Milwaukee's Water Supply.* H. P. Bohmann. (86) May 10.
Building a Big Dam in Wilds.* (13) May 11.
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Power Possibilities of Federal Irrigation Projects. A. P. Davis. (13) May 11.
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Waterpowers Not a Liability. C. E. Grunsky. (111) May 13.
Feasibility of Electrochemical Industries at the Dalles, Oregon.* O. F. Stafford. (111) Serial beginning May 13.
Traveling Screens at Northwest.* Thomas Wilson. (64) May 16.
Advocates Private Development of Water Power. (Discussion before the National Conservation Congress.) (64) May 16.
Liquid Manometers for Light Pressures.* R. S. Bayard. (64) May 16.
Handling of Water Main Extension Projects at Washington, D. C. (86) May 17.
Railway Electrification and Cheap Water Power.* Water Power Development Association. (86) May 17.
Rapid Tunneling in Brazil.* J. C. Balcomb. (13) May 18.
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PAPERS AND DISCUSSIONS

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PAPERS AND DISCUSSIONS

ADDRESS AT THE ANNUAL CONVENTION, IN PITTSBURGH, PA., JUNE 27TH, 1916.

By Clemens Herschel, President, Am. Soc. C. E.

As we approach the number in our order of exercises, which by Constitutional provision calls upon the President to deliver an Address at the Annual Convention, you no doubt feel, as I feel, that we stand in the shadow of the great loss this Society has suffered in the death of its duly elected President, Dr. Elmer Lawrence Corthell. Succeeding to his duties and responsibilities, I have endeavored to follow out any plans he may have had for the Address which he was to have delivered, but have been unable to learn that he left any definite written or oral memoranda with regard to it. "The night cometh when no man can work"; and it came to our late President, before he could communicate to others the thoughts he no doubt had with regard to this address, and had intended to incorporate in it.

It will not be foreign to his desires and aspirations, however, if I choose for the subject of our considerations, a topic that may well enlist the co-operation of us all; left to struggle with the world's work now that he is gone. Just 25 years ago, this your President was the newly elected President of the Boston Society of Civil Engineers; an engineering Society, let it be noted in passing, which was chartered in 1848, and which is thus the oldest organized engineering Society in the United States. At that time he chose for his subject: "The Advancement of the Profession of the Civil Engineer",*

* *Journal,* Assoc. of Eng. Societies, March, 1891.

and I have found it interesting to read what a younger man of the same name as myself (little else remains exactly the same between us), had to say on this subject 25 years ago. So much so, that I have ventured again to choose this subject, ever old, ever new, for your contemplation to-day.

We have had of late in the technical press and in the proceedings of engineering societies, ample evidence that the advancement of the profession of the civil engineer is a cause that still has the earnest attention of the large body of thoughtful working engineers of the country. The spirit of unrest has been abroad among them, and however much, content with one's individual lot may be ethically or religiously proper, and bringing blessings in its train, yet is unrest in behalf of one's class, and an altruistic, lawful striving to better the lot of that class, a commendable, and perhaps the only effective means of achieving that end, as experience has amply shown. Engineers feel that they occupy a prominent place in the creation of the world's material welfare, and want a recognition of this fact—a recognition that a share in the world's honors is due them, in the minds and actions of their fellow-men. Especially is their unrest and a striving for increased public recognition justifiable and prominent among engineers, when the creation of State or public works is under consideration.

Time was in this country, about 100 years ago, when it was denied that a State, or the United States, should undertake any, what were then called, "Internal Improvements"; what would now be called:—Public Works. We still suffer from that self-delusive attempt to ignore necessities that always have existed in countries reckoned civilized, or progressive; that always will exist. Wars and combats by land and sea, also in the air and underneath the sea, more than ever form mile-stones in the life of nations, as it is described in history; but the silent changes wrought by custom, and without bloody contest, in that same national life, are no less marked when viewed in a calm review of the centuries. What was natural and without material harm 100 years ago, has now become burdensome, and to thinking men, absurd.

Consider the state of society in this country in which could be passed a vote in town meeting (you may read it in the annals of a certain Connecticut Valley town), that "Cornelius the Irishman have

leave to take up land, but provided he have no voice in the town affairs"; and compare it with the state of affairs to-day in that same town, the stock derived from its original population submerged, even wholly extinguished, under the output of a "melting-pot", into which have been cast, at one time or another, specimens from all the nations of the earth; many of them of a most uncouth form and texture. Hardly less opposite is the need and propriety of public works to-day, as compared with that need and propriety in the young nation of 100 years ago, barely emerging from its colonial condition, and from a wilderness, apparently left on earth on purpose for it to subdue.

Says the poet:

> "Bid the broad arch the dangerous flood contain,
> The mole projected break the roaring main;
> Back to his bounds their subject-sea command,
> And roll obedient rivers through the land,—
> These honors Peace to happy nations brings;
> These are imperial arts, and worthy kings."

Public works have been deemed the glory of long-established, or developed, States, since the dawn of history. To attempt to do without them, or to rely solely upon private enterprise to procure them, is a mere delusion; or notion; impracticable; and yet we have a National, and, generally speaking, forty-eight State Governments, that make no permanent provision for their construction and up-keep, in their organic law.

The expenditure of 4% of the annual United States Budget on public works is made the foot-ball of politics, and great is the cry of victory when this expenditure has been reduced to 3½%; but no word is heard about the other 96 or 96½% of expenditure of the same budget; because public works are not recognized in the Constitutions of the United States and of the States, to the extent of providing a department of the Government, and permanent officers of the Government, to construct and care for them. A large part of the lack of recognition of the civil engineer as a member of an honorable profession, and of his merits, is, in my belief, traceable to this very state of affairs.

From time to time, the technical press contains discussions as to the anomalous position held by "Junior Engineers", and "Assistant Engineers" in the service of the United States, on public works, in

charge of the Corps of Engineers, U. S. Army; the former of whom can never rise above their basic position, and the best of whom consequently leave that kind of a service as quickly as circumstances will permit. These discussions are carried on in all sorts of tempers, and, to make my own temper clear in the matter, let me express the belief, founded on long personal observation and friendships, that there does not exist, an abler, a finer body of men than this same Corps of Engineers, U. S. A. Think of its genesis. A boy must have ambition, must be a select boy, to aspire to go to West Point. Competitive examinations, in the majority of cases, cull out the best of these to go there. Four years' training and schooling, and their consequent process of selection, reduces the number who enter, to the half that is able to graduate. And of these, only the four or five at the head of the class go into the Corps of Engineers. Evidently the population of the United States cannot produce better men than these four or five, thus marked for high honors. The trouble is not there. It is because the whole system of carrying on the civil engineering works of the United States is an emergency makeshift; born of a denial of the propriety of the nation to build *any* civil engineering works, and of the *necessity* of building them, when their construction could no longer be avoided, by makeshift methods.

In one, perhaps the best, of these discussions,* that have just been referred to, is contained this closing argument:

"Will any one maintain that it [Congress] is yet prepared to commission men as Civil Engineers and give them a similar [to Army, Navy, Revenue Cutter, etc.] legal status?" And if we are to stop there, the argument is no doubt a sound one. So long as Congress is not "prepared" to commission Civil Engineers to do the civil engineering work of the United States Government, that work will have to be carried on as an emergency measure, and not as a regular function of government. But this is the day of "preparedness", and sooner or later, Congress also will have to become "prepared", in this, as in many other matters.

Says Laurence Sterne, in his "Sentimental Journey": "They order this matter better in France". And not only in France, but in every country of the globe, except in Great Britain, and in the United

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* *Engineering News*, May 14th and June 11th, 1908.

States; the copyist of Great Britain, which the United States has been for so long, and in so many directions. The first named, all have a Ministry of Public Works, and, carrying on the business of this department, a corps of commissioned civil engineers. To that must the United States, and every State in the Union, come, sooner or later. Commissions of laymen to rule in these matters, appointed as an emergency measure, are an anomaly in these days of a striving for efficiency. See what says the President of the Institution of Civil Engineers, of Great Britain, James Charles Inglis, in his Annual Address for 1909. He quotes an economic authority to the effect that in the great struggle of the Twentieth Century it is in other countries the aim to leave as little as possible to chance; not to allow people to muddle through *somehow,* but to eliminate as far as possible the element of the unforeseen, while carefully training the mind to cope, in an intelligent way, with any emergency.

While the British had as a rule a violent suspicion of the expert, and a strong belief in the untrained, unpaid amateur as the bright source of wisdom, allowing the expert to advise and the amateur to decide, elsewhere there was no fear of the expert. There was indeed the possible danger of red tapeism at the hands of highly trained officals, but they would be found less than the dangers arising from the decisions of well-meaning but untrained and inexperienced amateurs;—all of which is applicable to the description of a contrast between the British and all the other European; between the United States method and a *rational* procedure in the construction and administration of public works.

Says President Inglis:

"If these principles were more acted upon in this country [Great Britain], as in time they must be, I think you will agree with me that many members of the Institution would find increased scope for their energies, and added interest in the engineering problems they have to deal with, while, without doubt, better results would, on the whole, ensue for capital."

Let me illustrate how the Commission habit in State Government operates; as philosophically viewed from a distance, in recent years. A certain State conceived the idea that it would be well to develop its principal seaport by works of the civil engineer. So a Commission of laymen was immediately created to cause this to be done. The

newspapers were replete for months as to who should be the Chairman of this Commission. There was a good salary attached. Not a word as to the Civil Engineer capable of designing the necessary works, and of wisely superintending the expenditure of millions of dollars in the future. Not one word. At length the die is cast, and the favorite of the "plum-tree" enters upon a course of the, at such times customary after-dinner speeches. After months of this sort of thing, and when the novelty of the situation has worn off, not much has been heard in the daily press as to the work to be done. An engineer has indeed been somehow appointed, and certain work planned and done. Then the former after-dinner speaker resigns, or is crowded out,—it is immaterial which,—changes of political government affect and *debase* the at-no-time illustrious commission and engineering corps, and the last end of that Commission is worse than its inception;—it is *itself* swallowed up and abolished in a reshuffling of the Commissions of the State generally; and all this in the space of barely 5 years; with the simultaneous hazard of millions of money to be expended, at once and in maintenance and repairs, or reconstruction in the future, in a foot-ball game of politics.

Is it not true, does one not see, in contemplating such bits of contemporaneous history, that especially in a Republic, are commissioned civil engineers needed for the proper carrying on of the public works of the State? The reason the average Congressman, even the Executive, respects the Army Engineer, as they do, is because the former knows that the services of the latter in and to the Government will go on, when he himself will not unlikely have been wholly forgotten. He would equally respect the commissioned civil engineer.

The layman Chief-of-Bureau's tendency to lack of consideration for his expert subordinate must be checked by the expert's permanence in the service, or else we can get no results in public works such as the State ought to have.

To illustrate again, where else than in the United States would it have been possible for a dreamer of patriotic visions, in the service of the Government, to have seen those visions come true under his able guidance in the space of some 15 years, and at an expenditure of scores of millions of dollars; creating empires of arable land, where before was the desert; and after the threat of political removal

by one brief layman incumbent of the chair at the head of his bureau, finally be made to succumb, without any justification that the public ever heard of, by another such brief incumbent, to the already manifested harm of the service, and of its future.

No amateur ruling the immediate present, of an important government work and agency, should have such subversive powers of harm for their future. No matter even that he act from motives which to him at the moment seem wholly good. He may be mistaken. Certain it is that a system that enables a mere passing temporarily exalted incumbent of an office thus radically to disorganize, out of his own mere motion, a work of national usefulness and importance, is not for the good of the body politic.

In a republic, with its short-lived, kaleidoscopic, ever-changing individual leadership form of government, even more than in a conservative monarchy, the servants of the State on public works, should have fixity of tenure of office. Verily, "they order this matter better in France"; a republic; and both better, and *by the same means* better, in many a country, besides France.

More could be said in the same line of argument and illustration, but the President's Address should not be tiresome, though the advancement of the Profession of the Civil Engineer can be viewed from many another angle. Indeed, in contemplating it, one is reminded of the lament of the New England conscience,—no one felt it more than he whom inadequately I am trying to replace to you,—"so much to do; so little done".

We have, for instance, the work of combining the efforts of the various branches of the Engineering Profession, in matters of their common interest. According to Section 2 of Article II of our Constitution, there are no engineers, except civil and military engineers; the original class distinction. But so various are to-day the occasions when it is necessary to apply "the art of directing the great sources of power in Nature for the use and convenience of man", that it long ago became impracticable to have all engineers in the United States enrolled in one American Society of Civil Engineers. Instead, we have the four prominent National Engineering Societies, and many amply useful, though less prominent, such engineering Societies. And yet the number of their aggregate membership is small, compared with

the population which they serve; a prominent reason why their expressed desires are too often but as a "voice crying in the wilderness". To remedy this condition which confronts us, many have labored, in season, and out of season, to bring about joint action of the engineers of the United States in matters of a common interest. This Society has said that it believes in it, and as a step in that direction, as facilitating that sort of work, as a landmark and a beacon light to the public, that engineers are at their posts of duty and should be recognized and reckoned with, we have said that the building of the four Founder Engineering Societies on 39th Street in the City of New York shall represent to the public, the home of a power in the land. The step we have taken and which has been voted in the affirmative, 2 500 for, 390 against, is of course but a beginning. It has been worked for in a duly humble spirit, and on the principle of doing one thing at a time, but the beneficent end of that work no man can see. "Be of good comfort", Master Ridley Latimer cried at the crackling of the flames, "play the man! We shall this day light such a candle, by God's grace, as I trust shall never be put out." Not only not put out, but increasing through the years, in effulgence, glory to the profession, and in usefulness.

I have said that the advancement of the Profession of the Civil Engineer in the United States, could be viewed from many another angle. This has nigh exhaustively been done by one of our distinguished fellow-members in a paper read February 29th, 1916, in this very city.*

There is the education of the engineer properly to be attended to. Is he, while thus in embryo, doing 24 hours of work and refreshment, in the 24 hours of the day? Is the work he is doing of the right kind?

We have many able fellow-members who are giving the travail of their lives to answer these questions.

There is reform within the active profession to be attended to. Is the typewriter machine and printing press already working overtime; running away with the drafting table and with service on the work and in the field, and with learning from Nature by experiment? What constitutes a legitimate consulting engineer? Not in the eyes of the great discerning public, but rather in those of his professional brethren.

* To be, or already published, by the Engineers' Society of Western Pennsylvania; a paper by J. A. L. Waddell, M. Am. Soc. C. E., of Kansas City, Mo.

Legislation in forty-eight States of the Union and in the Congress of the United States must be taken note of, to prevent harmful enactments, and to support those we know to be good for the body politic, no less than for the Profession of the Civil Engineer.

Not as a lamentation or a sigh of weariness, but as a cry and a call to additional, and to continued service to our profession and to mankind, let us say: As yet, *"So little done"*.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

This Society is not responsible for any statement made or opinion expressed in its publications.

TUNNEL WORK ON SECTIONS 8, 9, 10, AND 11, BROADWAY-LEXINGTON AVENUE SUBWAY, NEW YORK CITY

By Israel V. Werbin, Assoc. M. Am. Soc. C. E.
To be Presented September 20th, 1916.

Synopsis.

This paper describes the work of excavating for and lining the tunnels for the new Lexington Avenue Subway between 53d and 106th Streets, in the Borough of Manhattan, City of New York. Inasmuch as this work involved the driving of tunnels with large and unusual cross-sections, through unsound rock, under busy city streets, and the contract placed on the contractor absolute liability, it has been thought worth while to record the methods used.

The tunnels were built to accommodate two and four tracks, the two-track structure having a cross-section of 32 by 16 ft., the four-track, double-deck structure, 32 by 32 ft., and the four-track structure with all tracks on one level, 60 by 16 ft.

The methods followed in excavating these tunnels through sound and unsound rock and through soft ground are described. In some cases, water was encountered in such quantities as to necessitate the use of compressed-air methods, in order to prevent the loss of materials and the settlement of the local track structure which had

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

previously been completed. The excavation for the four-track structure with the four tracks on the same level had to be made one track at a time, and the manner of making this excavation and protecting the finished part of the structure are described.

Information is also given as to drilling, loading and firing, timbering, plant, cost, etc.

In connection with the lining of the tunnel with concrete, the various types of forms are described; also the manner of handling and placing the concrete.

General.

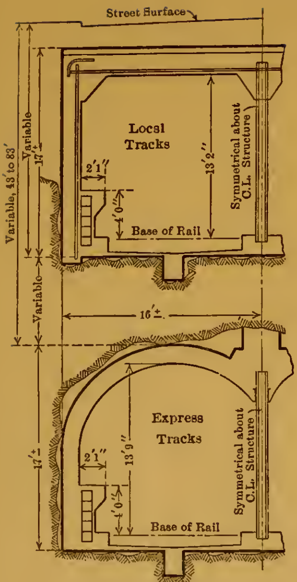
The Lexington Avenue Subway is being built by the City of New York, under the supervision of the Public Service Commission for the First District of the State of New York, and, when completed, will be operated by the Interborough Rapid Transit Company in accordance with contracts entered into with it by the City of New York acting by the Public Service Commission.

For purposes of organization and construction, the route is divided into sections averaging in length about thirteen or fourteen city blocks.

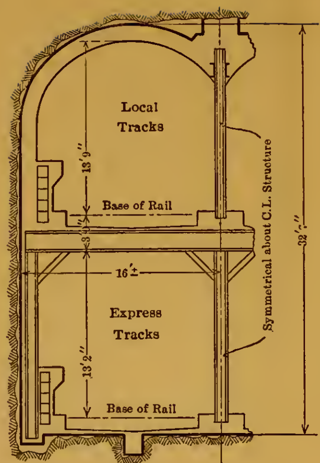
Section 8 extends from 53d to 67th Streets; Section 9 from 67th to 79th Streets; Section 10 from 79th to 93d Streets; and Section 11 from 93d to 106th Streets. The total length of the four sections is 13 992 ft.

The approximate quantity of tunnel excavation made on the four sections was 250 000 cu. yd., and, at the contract prices, the cost of doing this part of the work was approximately $2 250 000. The total cost of all the work on the four sections was approximately $10 500 000, exclusive of track, station finish, and equipment.

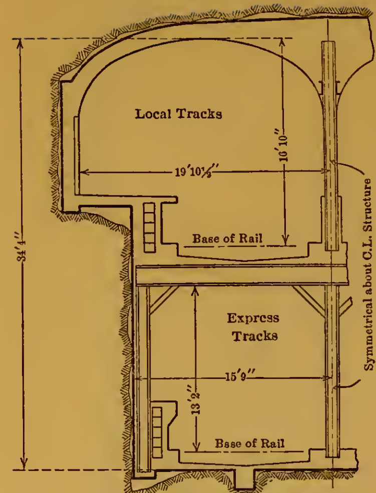
The rock encountered in the course of the work on these sections was mostly Manhattan schist of varying degrees of hardness. The greater part of the tunnel being but a comparatively short distance below the street surface, the rock was often blocky, and occasional mud seams were encountered, requiring considerable timbering on Sections 8 and 9. The rock on Sections 10 and 11 was fairly good, and very little timbering was used for this part of the work.



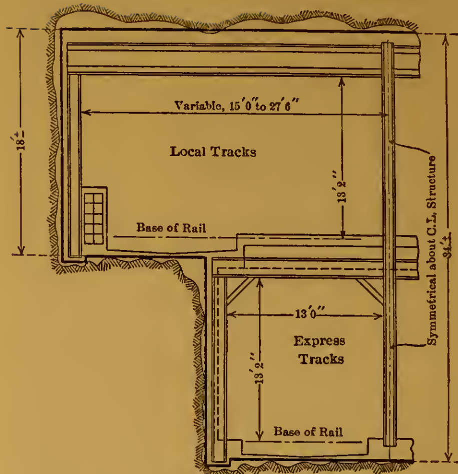
2-TRACK TUNNEL
53D TO 79TH STREETS.



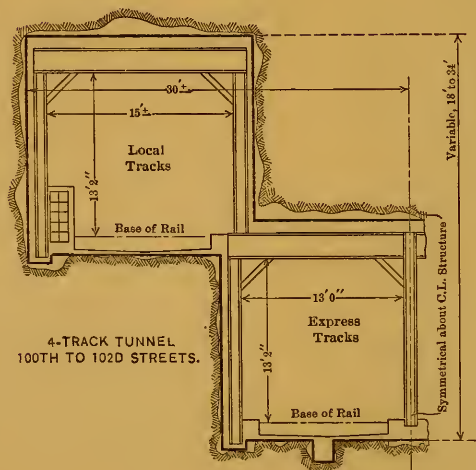
DOUBLE-DECK
4-TRACK TUNNEL
79TH TO 98TH STREETS.



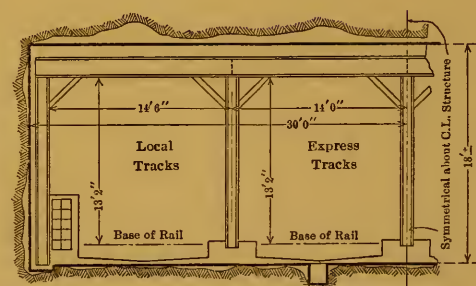
DOUBLE-DECK TUNNEL
WITH STATION IN UPPER LEVEL
96TH STREET.



DOUBLE-DECK
4-TRACK TUNNEL
98TH TO 100TH STREETS.



4-TRACK TUNNEL
100TH TO 102D STREETS.



4-TRACK TUNNEL
102D TO 103D STREETS.

TYPICAL SECTIONS
IN TUNNEL.
LEXINGTON AVENUE
SUBWAY
53D TO 103D STREETS.

General Description of Subway Structure.

Several different types of subway structure were used on the four sections. On Sections 8 and 9, the local and the express tracks are in separate structures. The local tracks are immediately below the street surface and the work was done by cut-and-cover methods; the express tracks are in separate tunnels below the local tracks. The distance from the street surface to the sub-grade of the express tracks varies from 60 to 100 ft., and the distance between the two levels from 10 to 55 ft., as shown on Plate VI.

The largest part of the structure on Sections 10 and 11 is double-decked, the express being placed immediately below the local tracks. This type prevails from 79th to 99th Streets. In the station at 96th Street, the upper level is widened to permit the construction of the station platform (Plate VI). Going north from 99th Street, the local tracks in the upper level diverge until at 100th Street they have been offset sufficiently to clear the express tracks in the lower level. The four tracks then continue northward on approaching grades until at 103d Street they are on the same level, as shown on Plate VI.

Excavation for Two-Track Tunnel, Sections 8 and 9.

Excavation in Sound Rock.—The excavation for these tunnels through sound rock did not present any exceptional features. The section was taken out with a center top heading and one or two benches, depending on the height of the heading. The center heading was about 9 by 14 ft., the drilling requiring from 24 to 32 holes, depending on the hardness of the rock. Work was carried on continuously for 24 hours per day, with three drilling shifts. The forces were organized so that an advance of about 5 ft. would be made daily. The details of the drilling, loading, and firing are shown on Plate VII.

Excavation in Unsound Rock.—In a considerable part of the work, the rock was hard but blocky, and would not permit of making the excavation for the full section without timbering. In most of these cases it was generally possible to excavate enough to permit the erection of the structure for one track without timbering, and after this part had been completed and the rock above had been caught up, the remainder of the section was excavated and the structure completed. (Fig. 1.)

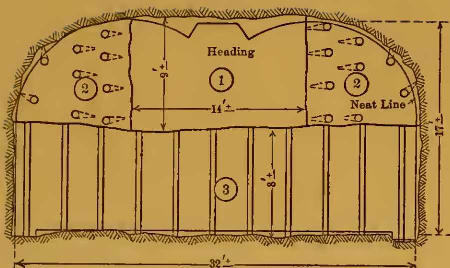
Where the rock was seamy and disintegrated, however, the top side-drift method of tunneling was generally used, segmental timbering being put in, as shown on Plate VIII. The side-drifts were generally about 7 by 11 ft. The wall-plates and timbering were set so as to be entirely outside the neat line of the subway structure and there would be no timbers bedded in the concrete lining inside the neat lines. Where soft ground was encountered, poling boards were driven ahead over the sets. The sets were placed about 2 ft. from center to center, 12 by 12-in. yellow pine timbers being used.

In the work on Section 8, where segmental timbering was used, the center pieces of the sets were posted up from the bench, and, as the latter was removed, new posts down to sub-grade were put in, as shown by Fig. 3. In removing the bench, the holes were drilled close together, and light charges of explosives were used in order to minimize the possibility of knocking out the posts. Toward the close of the job, in order to safeguard further this feature of the work, a long, continuous girder was blocked up under the center cap, and this was kept in place until the bench had been removed and new posts, down to sub-grade, had been placed. (Fig. 2.)

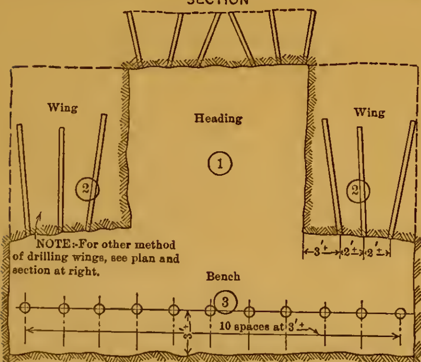
On Section 9, after the top heading had been removed, the contractor placed two (and in some cases three) pairs of 24-in. I-beams longitudinally on the bench, and the caps were posted up from these beams. (Fig. 4.) The beams were about 30 ft. long, and were spliced so as to develop their full strength. As the bench was removed, posts were placed under the beams down to the sub-grade. This system of timbering had the advantage that the posts under the caps did not have to be moved in order to make the excavation for the bench. (Fig. 5.)

Often, where the ground was heavy enough to require timbering, water was encountered, and it was desirable to keep this water away from the concrete lining until it had had time to set. Accordingly, the space between and back of the sets was packed with concrete, and later grouted under about 90 lb. pressure. This procedure was effective in keeping out most of the water, and also served to stiffen up the timbering. The final lining was placed tight up against the timber and concrete previously placed, and again grouted if necessary. (Fig. 6.)

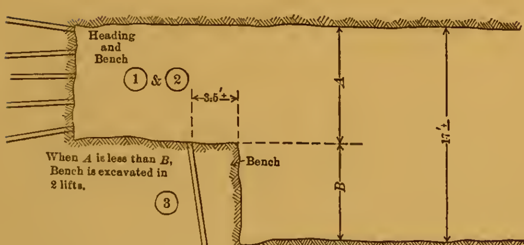
PLATE VII.
PAPERS, AM. SOC. C. E.
AUGUST, 1916.
WERBIN ON
SUBWAY TUNNEL WORK.



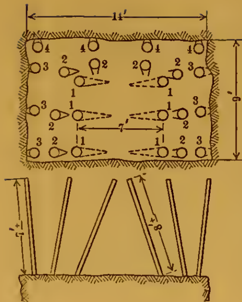
SECTION



PLAN



PROFILE



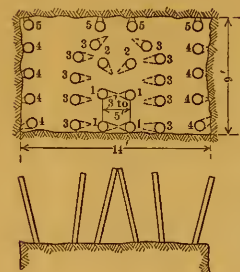
Number of holes.	Description of holes.	Depth, in feet.	60% Forcite. Total loading, in pounds	Loading per hole. Sticks	Loading per hole. Pounds	Loading per foot in pounds.
6	Cut	8	24	6.68	4	0.500
8	Inside rd.	7.5	40	8.35	5	0.668
6	Outside	7	26	7.21	4.33	0.618
4	Dry	7	20	12.6	5	0.716

LOADING DATA

24-HOLE HEADING

Yardage of heading.	23.4
Total linear feet of drill holes.	178
Total pounds of 60% Forcite.	110
Linear feet of drill holes per cubic yard.	7.6
Pounds of dynamite per linear foot of hole.	0.62
Pounds of dynamite per cubic yard.	4.71

Pull = 5 ft.



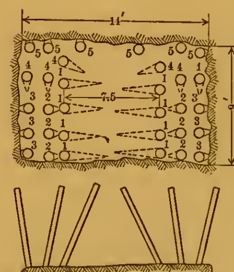
LOADING DATA

Number of holes.	Description of holes.	Depth, in feet.	60% Forcite. Total loading, in pounds	Loading per hole. Sticks	Loading per hole. Pounds	Loading per foot in pounds.
4	Cut	7	12	6	3	0.428
2	Breaking	6	0	5	3	0.500
10	Side	6	30	5	3	0.500
8	Side	6	24	5	3	0.500
4	Dry	6	8	3.33	2	0.333

28-HOLE HEADING

Yardage of heading.	21.1
Total linear feet of drill holes.	172
Total pounds of 60% Forcite.	80
Linear feet of drill holes per cubic yard.	8.17
Pounds of dynamite per linear foot of hole.	0.466
Pounds of dynamite per cubic yard.	3.79

Pull = 4.5 ft.



LOADING DATA

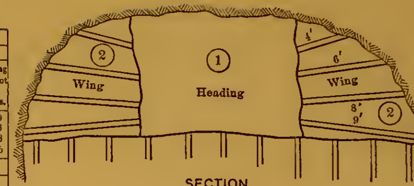
Number of holes.	Description of holes.	Depth, in feet.	60% Forcite. Total loading, in pounds	Loading per hole. Sticks	Loading per hole. Pounds	Loading per foot in pounds.
8	Cut	8	30	6.25	3.75	0.460
6	Side (1)	7.6	18	5.0	3.0	0.400
6	Side (2)	7.5	18	6.0	3.0	0.400
6	Breaking	7.5	11.4	3.18	1.6	0.254
6	Dry	7.5	12.6	3.50	2.1	0.281

32-HOLE HEADING

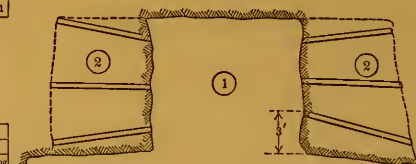
Yardage of heading.	28.0
Total linear feet of drill holes.	244
Total pounds of 60% Forcite.	90
Linear feet of drill holes per cubic yard.	8.72
Pounds of dynamite per linear foot of hole.	0.368
Pounds of dynamite per cubic yard.	3.21

Pull = 6 ft.

CENTER HEADING DIAGRAMS AND TABLES.



SECTION



PLAN

LOADING DATA

Drill Holes No.	Drill Holes Description	Depth, in feet.	Total linear feet.	60% Gelatin Dynamite Per hole. Sticks	Per hole. Pounds	Total pounds.	Pounds per foot.
CENTER HEADING							
4	Cut	7	28	6	3	12	0.420
2	Breaking	6	12	6	3	6	0.500
10	Side	6	60	6	3	30	0.500
8	Side	6	48	5	3	24	0.500
4	Dry	6	24	3.33	2	8	0.333
SIDE-WINGS							
7	Rib	8	66	6.67	4	28	0.500
2	Dry	7	14	6.62	3.8	6.6	0.471
BENCH							
11	Bench	8	68	6.65	3.88	4.38	0.498

QUANTITIES FOR A 6-FOOT ADVANCE

	Center heading.	Side-wings.	Bench	Total
Yardage	23.1	26.	57.1	111.2
Total linear feet of drill holes.	230	143.	156.	529.0
Total pounds of dynamite.	106.6	70.2	80.6	257.2
Linear feet of drill holes per cubic yard.	8.17	6.50	2.72	4.76
Pounds of dynamite per foot of hole.	0.466	0.492	0.517	0.488
Pounds of dynamite per cubic yard.	3.79	2.70	1.41	2.32

SUMMARY

METHOD OF
TUNNEL EXCAVATION
2-TRACK TUNNEL
SOUND ROCK
SECTIONS 8 AND 9.

FIG. 1.—CONSTRUCTION IN POOR ROCK TUNNEL. HALF OF SECTION BUILT AT A TIME, WITHOUT TIMBERING.

FIG. 2.—SEGMENTAL TIMBERING USED ON SECTION 8; ALSO TYPES OF CENTER LINE STEEL USED IN THE TUNNEL.

Excavation in Compressed Air.—At 57th and 75th Streets, streams originally crossed Lexington Avenue, and when the excavation was being made for the express tunnels at these places, considerable water was encountered. The contractors had completed the structure for

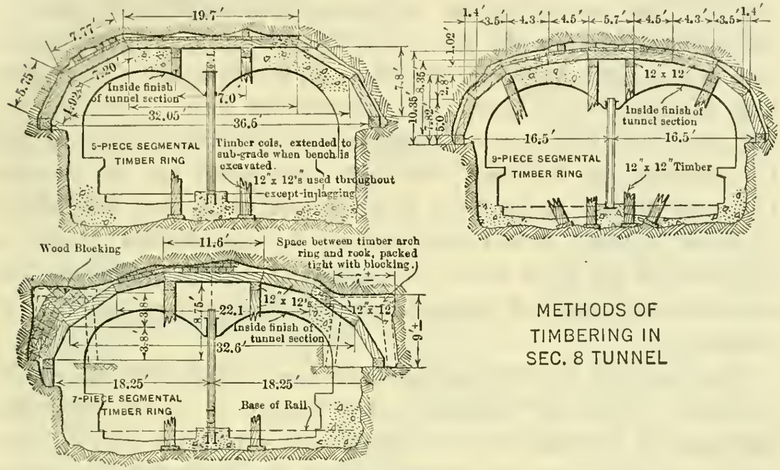


FIG. 3.

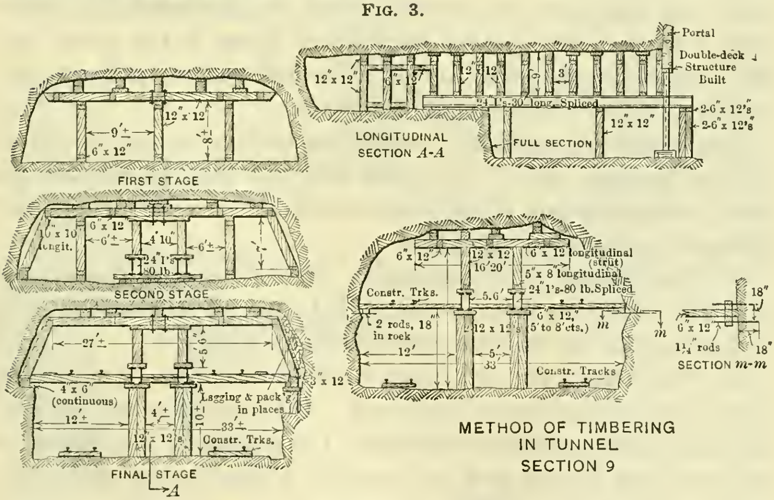


FIG. 4.

the local tracks in the upper level at these points before the work in the express tunnels was undertaken. This had been done in spite of the fact, pointed out to them, that settlement in the local track structure might result if soft ground carrying water was encountered

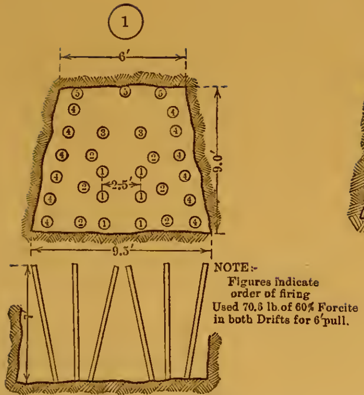
in the excavation for the express tunnel. As the excavation approached the sites of the old streams at 75th Street, the top of the section ran out of rock, and at 57th Street there were only a few feet of rock cover over the heading. In both places considerable water ran into the excavation, and the water, carrying with it some of the material between the two levels, caused considerable settlement in the local track structure, as well as some settlement in the buildings adjacent to the work. An attempt was made to control the settlement by blocking up the roof of the local track structure and by supporting the buildings temporarily on needles, also by pumping the water through driven wells from the local track floor, but neither of these methods proved satisfactory. It was decided finally to proceed with the work under air pressure, by which method the excavation was completed successfully without any appreciable loss of materials.

The details of the locks and bulkheads used at 57th Street are shown on Fig. 7. The air pressure varied from 8 to 16 lb. Concrete bulkheads, 3 ft. thick and reinforced with structural steel or iron rails, were built into the finished section of the tunnel. A groove about 6 in. deep was cut into the concrete lining of the tunnel, and the bulkheads were bonded into it. The lock and the pipes for air, drainage, etc., were built into the bulkheads.

The excavation under air pressure was confined to the removal of the top heading. After the timber sets had been placed and the space between and back of the timbers had been concreted and grouted, the bench was removed in free air.

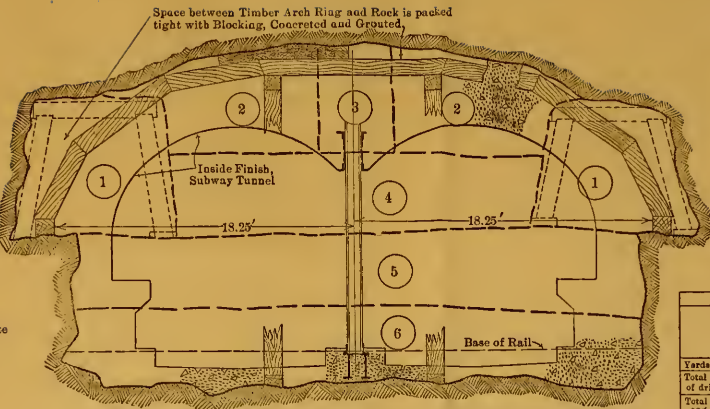
At 57th Street, where the section did not run out of rock, the excavation under air pressure was made by the top side-drift method, as described for the unsound rock tunnels on Section 8.

At 75th Street, the top of the heading was driven through soft ground, and poling boards were used. The general method of procedure (Fig. 8) was about as follows: The excavation was started at the center and carried over to the sides. Poling boards, about 4 ft. long, were driven over the caps, and, as the excavation was carried from the center to the sides, breast boards were placed against the face of the heading and under the ends of the poling boards, until the excavation had been widened enough to permit the placing of another cap, after which the breast boards were removed and the

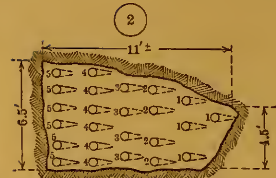


NOTE:- Figures indicate order of firing
Used 70.6 lb. of 60% Forcite in both Drifts for 6′ pull.

DRILLING DIAGRAM - DRIFTS.



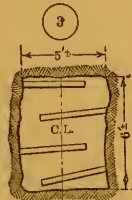
SECTION SHOWING ORDER OF EXCAVATION.



DRILLING DIAGRAM
TOP HEADINGS.
Used about 23 lb. for a pull of 4′ in both top headings.

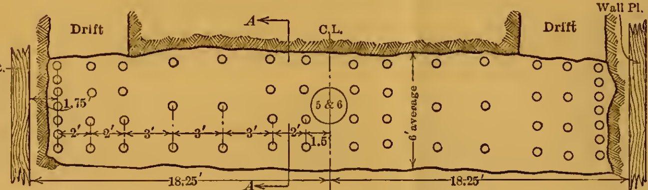
DRILLING AND LOADING DATA.

QUANTITIES PER LINEAR FOOT OF TUNNEL.	East and west drifts	East and west top heading.	Center line core.	Top bench.	Top and bottom lifts, lower bench.	Complete section.
Yardage.	5.17	4.60	1.11	4.58	9.78	25.24
Total linear feet of drill holes.	72.	67.5	7.5	55.	109.5	301.6
Total pounds of 60% Forcite.	11.75	5.75	0.63	13.5	24.5	56.13
Linear feet of holes per cubic yard.	13.95	12.5	6.76	12.	11.2	11.9
Pounds of 60% dynamite per cubic yard.	2.27	1.25	0.57	2.94	2.51	2.23
Linear feet of drill holes per linear foot of 2-track tunnel = 83.51.						



For a pull of 4′, Used 2½ lb. of Dynamite.

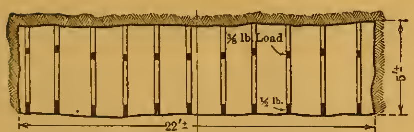
EXCAVATION OF CENTER LINE CORE.



PLAN OF DRILL HOLES IN LOWER BENCH, 2 LIFTS.

LOADING DETAILS.

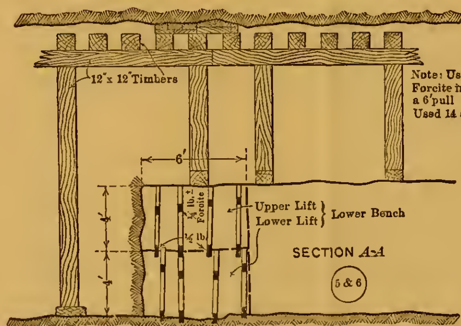
Pull in feet.	Holes. No.	Holes. Description.	Depth, in feet.	Total pounds.	Pounds per hole.	Loading per foot of drill hole, in pounds.
	EAST AND WEST DRIFTS. ①					
6	12	Cut holes.	8	18.0	1.5	0.19
	18	First round.	7	22.5	1.25	0.18
	30	Second round.	7	30.0	1.0	0.14
	EAST AND WEST TOP HEADINGS. ②					
4	46	Hammer.	5	23.0	0.6	0.10
	CENTER CORE. ③					
4	8	Cut holes.	5	2.5	0.42	0.09
	UPPER BENCH. ④					
1	11	Cut holes.	5.5	9.5	0.87	0.16
	30	Trimming.	4	4.0	0.13	0.33
	LOWER BENCH, TWO LIFTS. ⑤ ⑥					
6	146	Breaking.	4.5	147.0	1.01	0.23



METHOD OF EXCAVATING UPPER BENCH.

Note: (1′ pull) used 13.6 lb. of dynamite in 11 breaking holes and 30 trimming holes.

4



Note: Used 147 lb. of 60% Forcite in Bench (5 & 6), for a 6′ pull
Used 14 shots.

METHOD OF EXCAVATION
IN
UNSOUND ROCK
2-TRACK TUNNEL
SECTIONS 8 AND 9

FIG. 5.—METHOD OF TUNNEL TIMBERING USED ON SECTION 9.

FIG. 6.—SPACE BETWEEN TIMBER SETS CONCRETED.

operation was repeated. After three or four caps had been placed in this way, the excavation was widened out for the wall-plates and side-legs. Where considered necessary, lagging was placed and braced, as shown on Fig. 8.

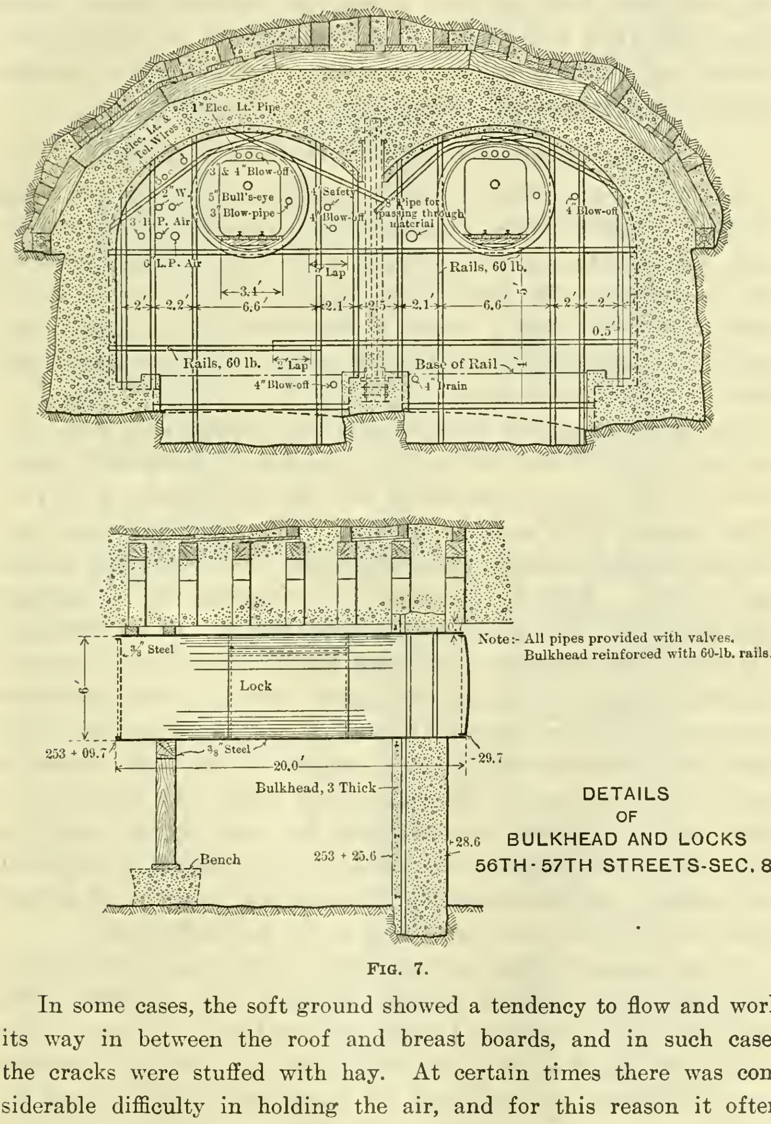


FIG. 7.

In some cases, the soft ground showed a tendency to flow and work its way in between the roof and breast boards, and in such cases the cracks were stuffed with hay. At certain times there was considerable difficulty in holding the air, and for this reason it often

became necessary to caulk the cracks between the timbers with oakum and clay.

Working Shafts.—There were working shafts, for handling the excavated material from the express tunnels on Sections 8 and 9, at 56th, 62d, 68th, 74th, and 78th Streets, the distances between shafts being 1 605, 1 662, 1 518, and 1 057 ft., respectively. At 62d and 74th Streets, the hoisting was done with electric traveling cranes; derricks operated by electric hoists were used at the other shafts.

Roadway Support at Portals, Sections 10 and 11.

The tunnels on Sections 10 and 11 were not continuous, there being stretches of open-cut work between them. The excavation was generally started at the cut-and-cover part of the work, and then extended into the tunnels. The depth of the cuts between the portals varied from 50 to 70 ft., and it became evident that some method of supporting the roadway, different from the usual one of posting up from below, would have to be used.

Two general methods of supporting the roadway were used. By the first, 48-in. girders, 60 ft. long, were placed about 40 ft. apart across the full width of the trench, with the ends resting on the rock or on cribbing built up from the rock. Then 26-in. I-beams were run longitudinally over the cross-girders, and the roadway was blocked up from them. After the excavation was completed, the cross-girders were posted up from below, as shown by Fig. 9. As an additional precaution, 48-in. girders were placed longitudinally in the roadway alongside of the curb, and the cross-girders were connected with them by suspender rods and plates. The surface girders were spliced with a joint designed to develop the full strength of the girder before it would fail. One end of the longitudinal girder was supported by being blocked up from a cross-girder that was already posted up from below, and the other end rested on the undisturbed portion of the roadway. As the excavation advanced, the longitudinal girders were moved ahead, or an additional girder was spliced on.

By the second method, the longitudinal girders just described were used, but 26-in. I-beams running crosswise were suspended from them, and the roadway was blocked up from these cross-beams. The beams were placed about 10 ft. from center to center, and, after the excavation below was completed, the beams were posted up and the longitudinal girders moved ahead. (Fig. 10.)

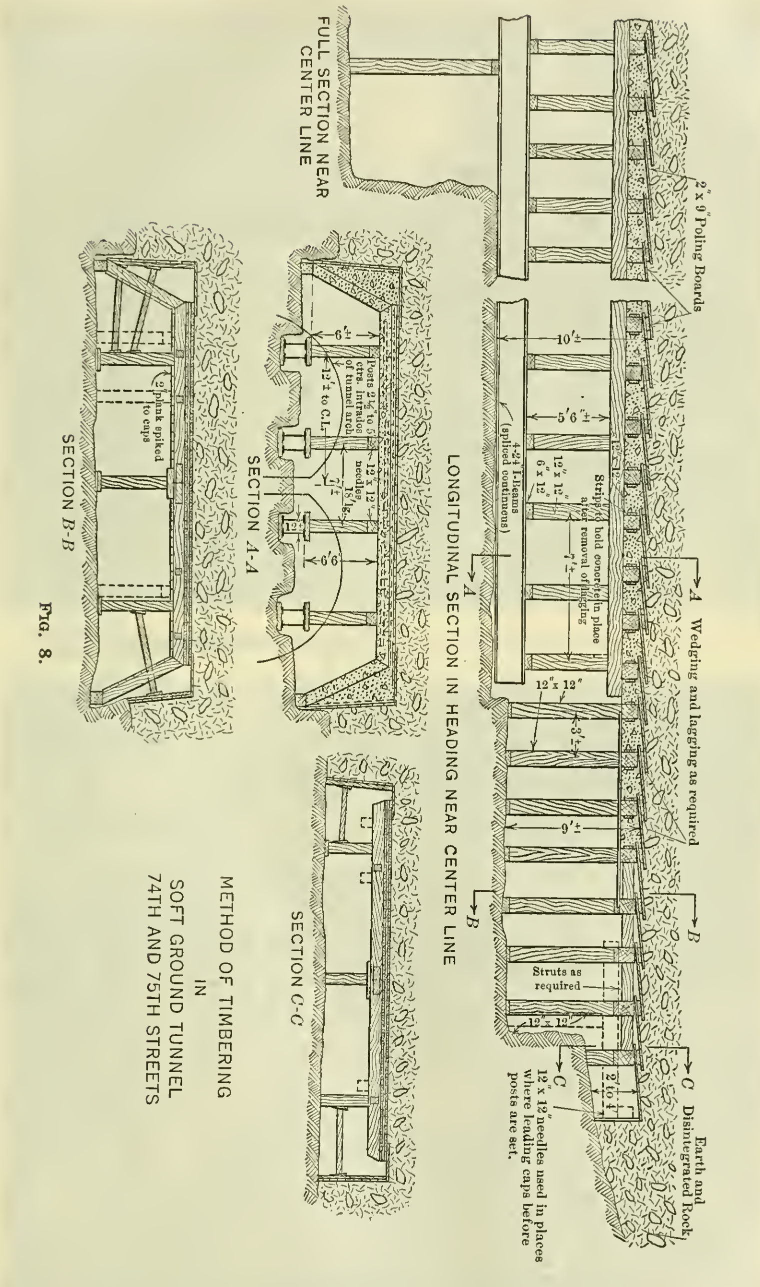

2" x 9" Poling Boards
A Wedging and lagging as required
B
C Earth and Disintegrated Rock
10'±
5'6"±
12" x 12"
6" x 12"
Strips to hold concrete in place after removal of lagging
7'±
4-24" I-Beams (spliced continuous)
12" x 12"
3'±
9'±
Struts as required
12" x 12"
2' to 4'
12" x 12" needles used in places where leading caps before posts are set.
LONGITUDINAL SECTION IN HEADING NEAR CENTER LINE
FULL SECTION NEAR CENTER LINE
6'±
Posts 2½' to 5' ctrs. intrados of tunnel arch
12'± to C.L.
12" x 12" needles
18"
6'6"
SECTION A-A
2" plank spiked to caps
SECTION B-B
SECTION C-C
METHOD OF TIMBERING
IN
SOFT GROUND TUNNEL
74TH AND 75TH STREETS

FIG. 8.

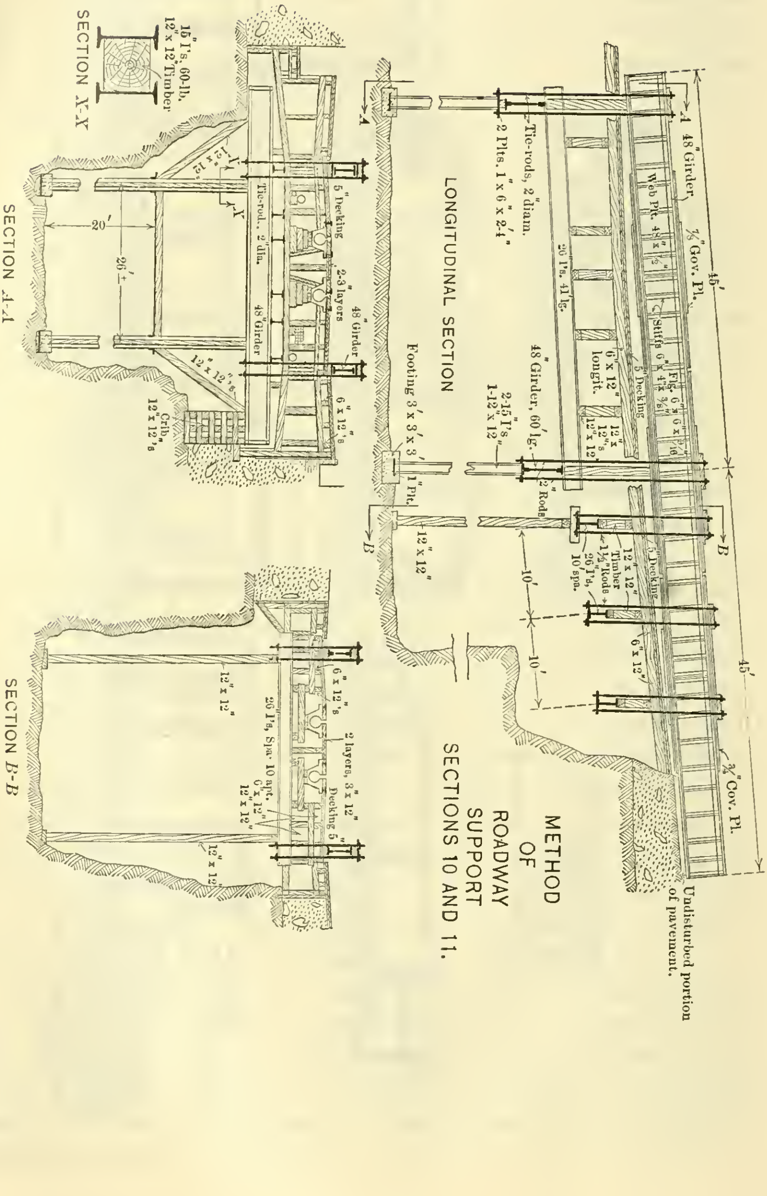

METHOD
OF
ROADWAY
SUPPORT
SECTIONS 10 AND 11.
LONGITUDINAL SECTION
SECTION X-X
SECTION A-A
SECTION B-B

Fig. 9.

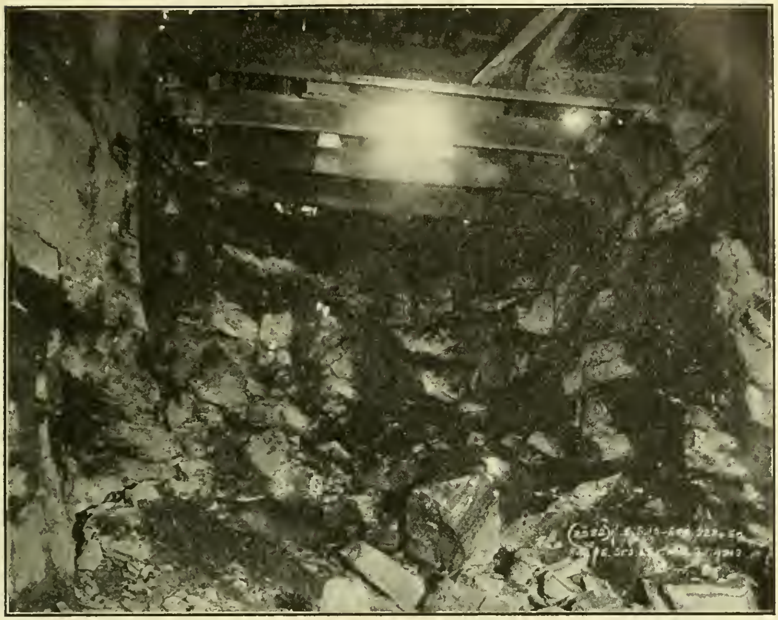


Fig. 10.—Roadway Supported on Cross-Beams, Sections 10 and 11.

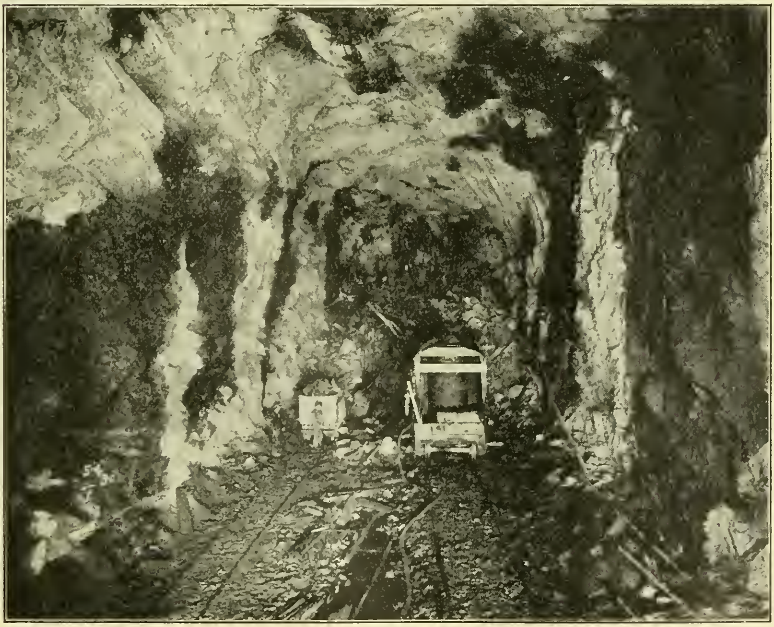


Fig. 11.—Excavation in Double-Deck Tunnels.

Excavation for Double-Deck Tunnel, Sections 10 and 11.

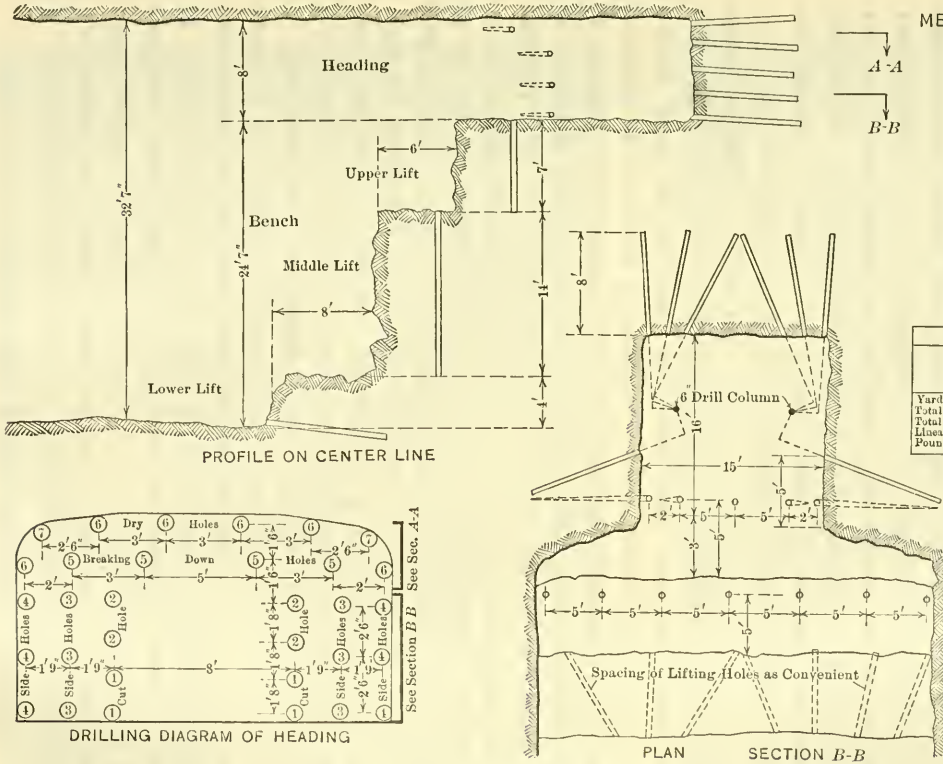
The double-deck tunnel is 31 ft. 8 in. wide and 32 ft. 7 in. high. The section was generally taken out with a center top heading and three benches. An advance of from 5 to 8 ft. of heading was made at each fire. About 8 lin. ft. of drill holes were required per cubic yard of heading, and 1.6 ft. per cubic yard of bench. The approximate arrangement of drill holes, and the loading and order of firing are shown on the heading diagrams, Figs. 12 and 13.

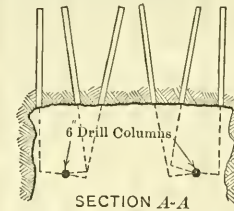
The excavation was started with a 32-hole heading (Fig. 12), but, owing to the severe concussion following the blasts, it was found advisable to increase the number of holes to 48 (Fig. 13) until the excavation was sufficiently advanced beyond the portal, so that the effect of the blasting would not be so severe. The depth of the cut was reduced from 8 to 6 ft., and the spacing of the holes in the bench was reduced from 5 to 3 ft. This new arrangement required much more drilling (4.7 lin. ft. per cu. yd. of excavation as compared with 2.5 lin. ft. previously used), but was efficacious in reducing the concussion and the subsequent vibration of adjacent buildings and breaking of windows. After the excavation had been carried about 250 ft. beyond the portal, there was little concussion noticed on the street, and the drilling was brought back to the 32-hole heading. (Fig. 11.)

In the prosecution of this part of the work, the aim was to make an advance of from 5 to 8 ft. in 2 days. In general, the center heading and the middle bench were fired on one day, and the upper and the bottom benches on the next. The advance in the heading varied from 5 to 8 ft., depending on the character of the rock; the sides and the benches were taken out about 5 ft. at a time, an extra shot being occasionally taken out of the sides and benches, so that the progress would keep up with that of the heading. The work was done with one mucking and two drilling shifts working as follows: Mucking gang, 10 A. M. to 7 P. M.; drilling gangs, 6 A. M. to 2.30 P. M., and 4.30 P. M. to 12.30 A. M. The blasting was done before the mucking gang came on (between 7.00 and 10.00 A. M.), and from 12 M. to 1 P. M., when the mucking gang stopped for lunch.

The best monthly progress in excavation in this tunnel was 100 ft. of full section, or about 3 700 cu. yd. of excavation within neat lines.

METHOD OF EXCAVATION
IN TUNNEL
32-HOLE HEADING





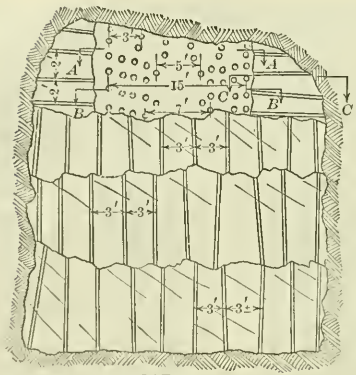
SECTION A-A

QUANTITIES PER 8 LIN. FT. OF TUNNEL.	Heading, center and side.	Bench.	Complete section.
Yardage	65	231	296
Total linear feet of drill holes,	890	362	752
Total pounds of 60% Forcite.	179.76	222.72	402.48
Linear feet of holes per cubic yard	6.00	1.57	2.54
Pounds of Forcite per cubic yard	2.7	0.96	1.36

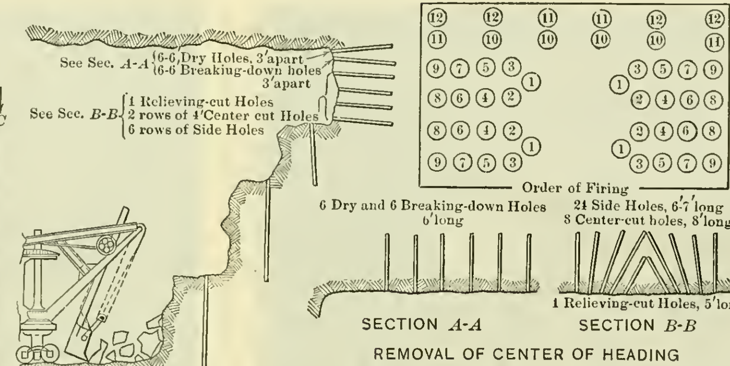
LOADING DATA

	No.	Description of Holes	Depth, in feet	Total Loading, in pounds	Loading per hole, in pounds	Loading per foot, in pounds
Per 8 Feet		CENTER HEADING				
	6	Center cut	10	38.4	4.8	0.48
	6	Side holes	9	25.2	4.2	0.42
	6	Side holes	8	21.6	3.6	0.45
	6	Breaking down	8	18.0	3.0	0.38
	6	Dry holes	8	22.8	3.8	0.47
		SIDE HEADING				
	2	Dry holes	7	6.2	3.6	0.51
	4	Side holes	9	16.8	4.2	0.47
	2	Side holes	10	9.6	4.8	0.48
Per 5 Feet		UPPER LIFT				
	2	Bench holes	12	12.0	6.0	0.50
	2	" "	9	10.8	5.4	0.60
	2	" "	7	9.6	4.8	0.69
		MIDDLE LIFT				
	7	Bench holes	14	58.8	8.4	0.60
		LOWER LIFT				
	8	Lifting holes	9	48.0	6.0	0.67

FIG. 12.



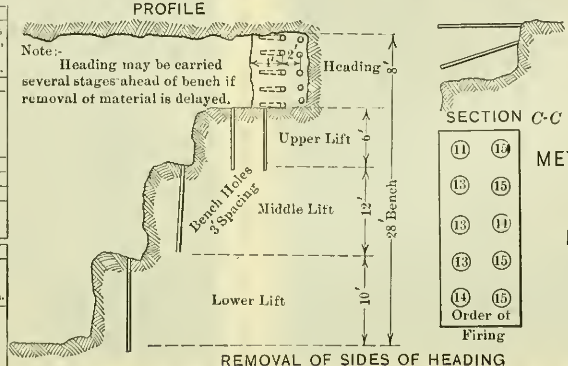
SECTION



LOADING DATA.					
Holes		Depth, in feet.	Total loading, in pounds.	Loading per hole in pounds.	Loading per foot, in pounds.
No.	Description				
CENTER HEADING.					
4	Relieving holes	5	7.0	1.75	0.35
8	Center cut	8	25.6	3.20	0.40
24	Side holes	6.5	46.8	1.95	0.30
6	Dry holes	6	10.8	1.80	0.30
6	Breaking-down	6	10.8	1.80	0.30
SIDE HEADING.					
20	Side holes	8	56.0	2.80	0.35
BENCH.					
10	Bench holes	6	21.0	2.10	0.35
10	" "	12	42.0	4.20	0.35
10	" "	10	35.0	3.50	0.35

QUANTITIES PER 6 LIN. FT. OF TUNNEL.			
	Heading center and sides.	Bench	Complete section.
Yardage	57	165	222
Total linear feet of drill holes.	472	560	1032
Total pounds of 60% Forcite.	157	196	353
Linear feet of holes per cubic yard.	8.3	3.4	4.7
Pounds of Forcite per cubic yard.	2.8	1.2	1.6

PROFILE



METHOD OF EXCAVATION IN TUNNEL 48-HOLE HEADING DIAGRAM

FIG. 13.

Trimming at Portal and Widening Out for Station Platforms.

Generally, only a few feet of rock cover was found at the portals, and, as this rock was seamy and disintegrated, the excavation was started about 5 ft. below the line of the finished roof and gradually brought up to grade in about 100 ft. At the 95th Street portal, where the work was in the station, no attempt was made at first to excavate for the station platforms, the contractor intending to come back later, after the lower level structure had been completed, and do this part of the work.

Before the portals were trimmed and the excavation was widened out for the station platforms, the plans were changed so as to substitute steel columns with longitudinal beams or girders on top for the reinforced concrete center wall originally called for. This change of plan greatly simplified the work, and lessened the risk of excavating for the station platforms and trimming at the portals.

As has been noted previously, the rock at the portals was very poor (Fig. 14), and particular care had to be taken not to expose too much of it at a time. The structure for the lower level was first completed (Fig. 16), and also for the upper level inside the portal, where the excavation had already been made to the full section. The work at the center was trimmed carefully to the neat line for about 20 ft., commencing at the point where the upper level had already been completed, and working toward the portal (Fig. 15). While the center was being trimmed, the rock on the sides was made secure by posting or cribbing from the roof of the structure of the lower level. The center line steel and concrete wall was then built for about 15 ft., and carried up solid to the rock above. After the rock was thus caught up at the center, the roof on one side was trimmed and the arch placed (Fig. 17), after which the other side was completed. In this way, by working from the finished structure toward the portal, trimming small stretches at a time, and keeping the exposed rock in the roof well supported, the trimming at the portals and the widening out for the station platforms were accomplished successfully.

Excavation, 99th to 102d Streets.

Between 99th and 102d Streets, the transition is made from a double-deck tunnel structure to one with four tracks on the same

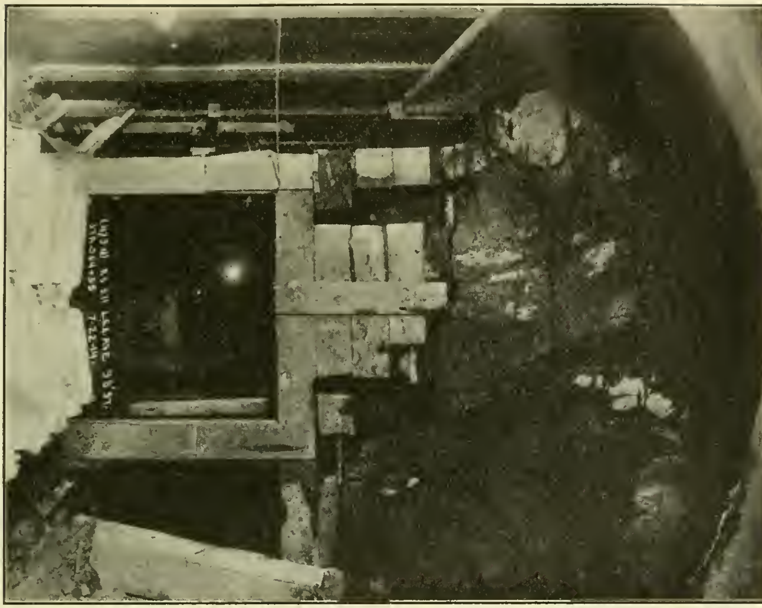
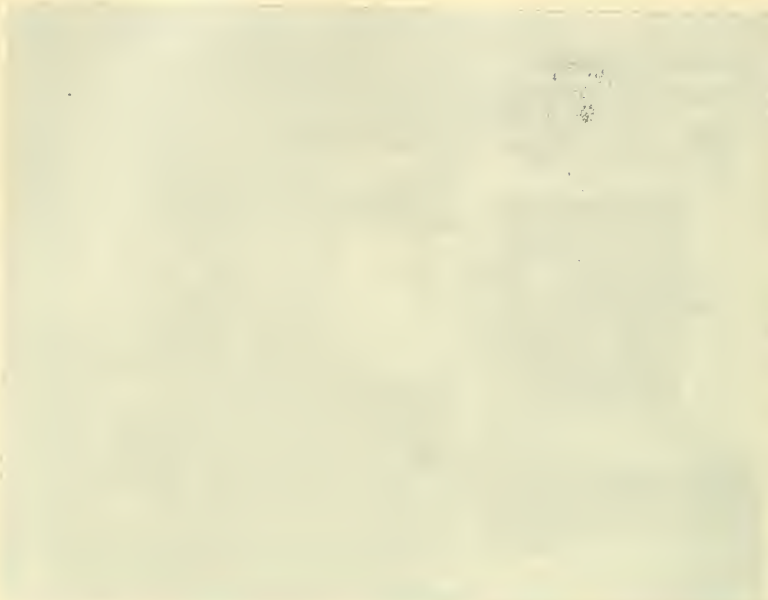


Fig. 14.—Typical Condition of Rock at the 95th and 96th Street Portals.

Fig. 15.—Center Wall Construction, 96th Street Station.



level. The span of the tunnel at 99th Street is 32 ft. (Fig. 19), and this gradually increases until, at 100th Street, the span is 60 ft. (Plate VI). At this point, the local tracks have been offset sufficiently to clear the two center tracks in the lower level, and continue northward in two separate one-track tunnels, the rock core between them (over the center tracks) not being removed. (Plate VI.)

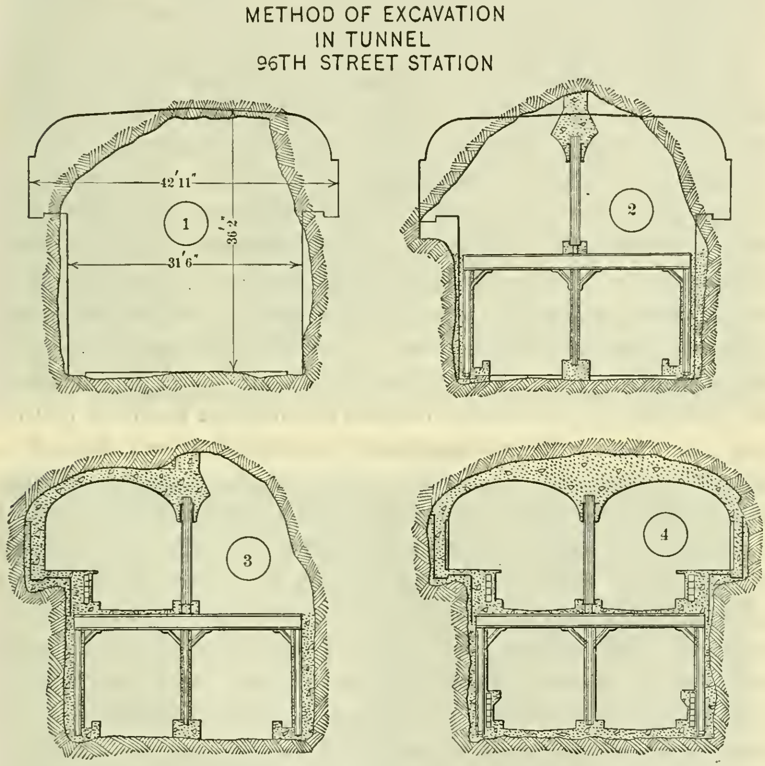


Fig. 16.

In making the excavation for the widening north of 99th Street, a section approximating that of the typical double-deck tunnel was first taken out, and the structure for the lower level completed. The roof was then trimmed at the center to permit the erection of the center steel, and, after the rock was solidly blocked up from the tops of the columns, the excavation was increased to its full width without requiring any additional timbering, except for occasional posting under unsound rock.

The most difficult part of the tunnel work on Lexington Avenue was the excavation for the transition between 100th and 102d Streets. The tunnel for this stretch had a span of 60 ft., and the rock was cut up and disintegrated, and would hardly stand without support for the span of one track (15 ft.). The situation was complicated further by the fact that the plans did not contemplate the excavation of the rock core over the center tracks (lower level) and between the local tracks on the sides.

The general scheme of prosecuting the work was to complete first the excavation for the center tracks, build this part of the structure, and, after the rock over the roof was properly caught up, to make the excavation for the local tracks on the sides. The excavation for the two center tracks was continued northward to about 100th Street without encountering any special difficulties. Going north from 100th Street, the rock began to get bad, and it became evident that it would not be safe to make the excavation for the full width of the two-track structure without the use of timbering. As the contractor desired to continue the use of his air shovel for mucking, and as the use of the ordinary methods of timbering requiring posting would interfere with the operation of the shovel, it was decided to narrow the excavation to a width of about 18 ft., this being sufficient to permit the use of the air shovel. The excavation was confined to one side, so that, when completed, the structure for one track could be built. It was hoped that the rock would arch for this small span, and that by this procedure there would be no necessity for timbering. This scheme was successful for the greater part of the work, but occasionally there were places where, even with such a small span, it was necessary to support the roof. In these cases, in order to permit the use of the air shovel for mucking, the timbering had to be placed so that it would not interfere with the shovel or with the construction that was to follow later.

The general manner of putting in roof supports in these cases (Fig. 21) was about as follows: When unsound rock was encountered, the excavation was advanced with a small heading (8 by 8 ft.), the rock in the heading being secured temporarily by posting. At a point where the excavation to the neat line had been completed previously, recesses were cut in the side rock above the line of the roof of the finished structure, and 24 or 26-in. I-beams were placed

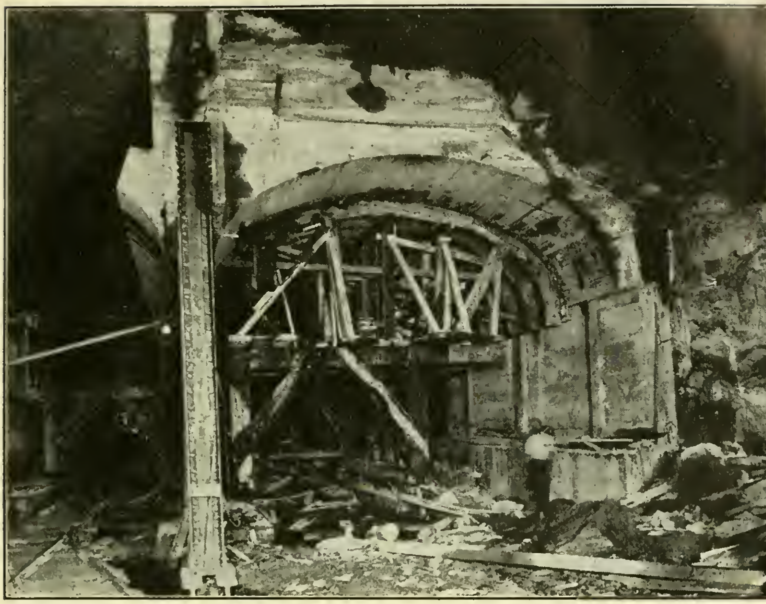


FIG. 17.—HALF OF ROOF IN 96TH STREET STATION CONCRETED.

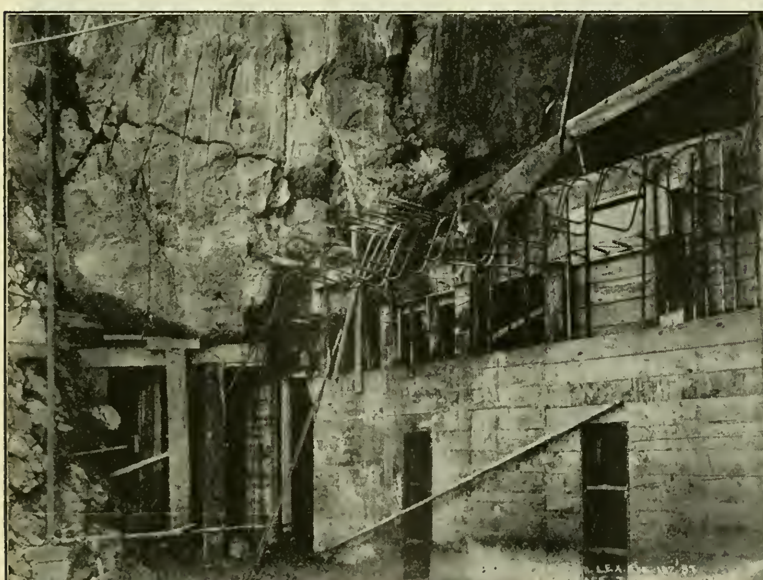


FIG. 18.—ROCK CONDITIONS AT 102D STREET PORTAL.

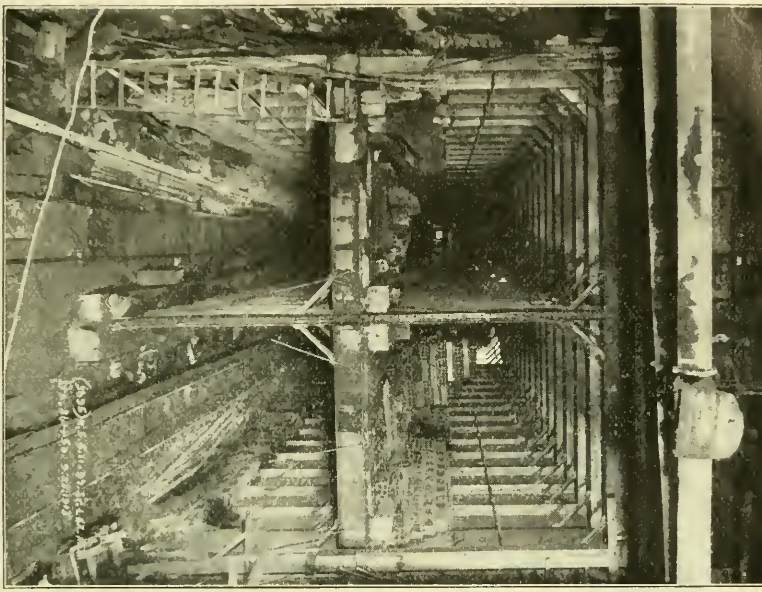


FIG. 19.—DOUBLE-DECK OPEN-CUT STRUCTURE AT 98TH STREET.

FIG. 20.—CONCRETE BUTTRESSES AGAINST 102D STREET PORTAL.

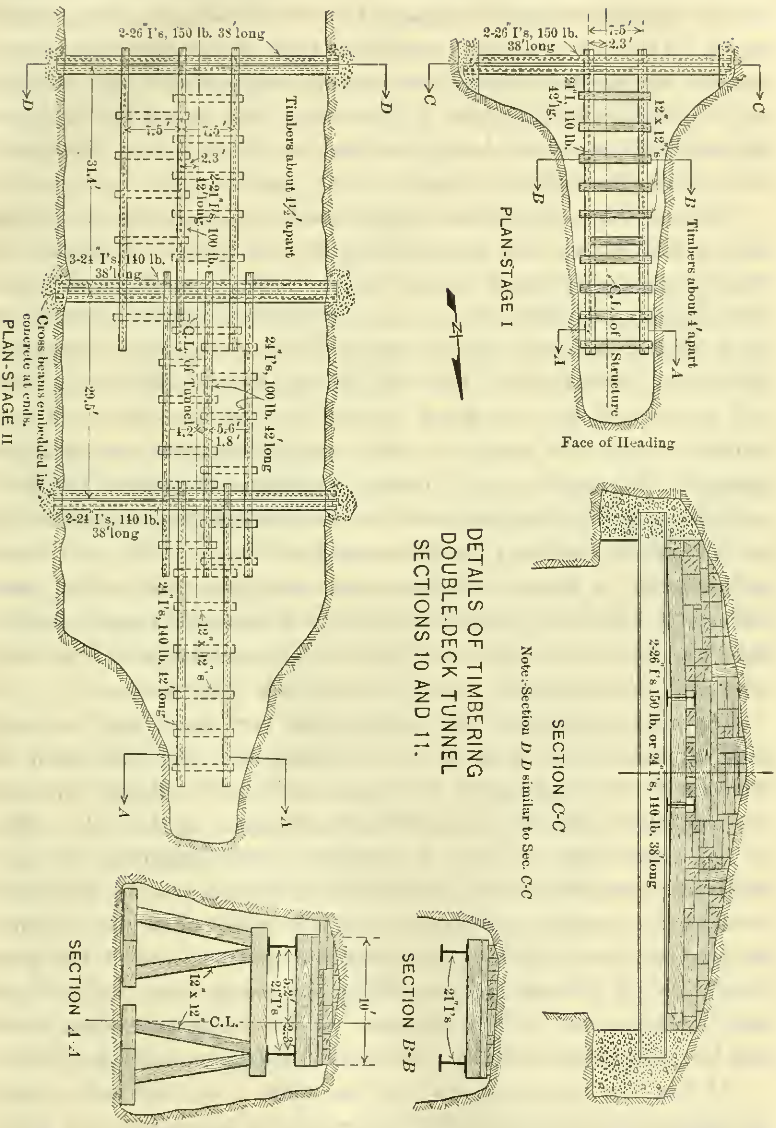

DETAILS OF TIMBERING
DOUBLE-DECK TUNNEL
SECTIONS 10 AND 11.
PLAN-STAGE I
PLAN-STAGE II
SECTION C-C
Note:-Section D D similar to Sec. C-C
SECTION B-B
SECTION A-A
Face of Heading
Timbers about 4' apart
Timbers about 1½' apart
2-26" I's, 150 lb. 38' long
3-24" I's, 140 lb. 38' long
2-24" I's, 140 lb. 38' long
24" I's, 100 lb. 42' long
24" I's, 140 lb. 12' long
2-21" I's, 100 lb. 12' long
21" I, 110 lb. 42' lg.
12" x 12"
Cross beams embedded in concrete at ends.
C.L. of Structure
C.L. of Tunnel
2-26" I's 150 lb. or 24" I's, 140 lb. 38' long
21" I's
10'

FIG. 21.

crosswise, with the ends of the beams concreted into these recesses. A temporary horsehead was then set up in the heading, and longitudinal beams were placed, supported on the horsehead and the cross-beams. The rock was then blocked up from the longitudinal beams, and the section was increased to its full width, after which another set of cross-beams was put in just below the horsehead, and the longitudinal beams were brought to bear on this new set. The small heading was then advanced another 50 ft., and the operation repeated.

These systems of timbering were used for about 200 ft. of the tunnel, and though they were efficient for the purpose of supporting the rock and permitting the use of the shovel, they interfered seriously with the progress of the work, as it took about a week to put in about 50 ft. of the timbering, during which period the work of excavation had to be discontinued. For this reason, toward the close of the job, the use of the air shovel was abandoned, the excavation was confined to only one track at a time, and all loose rock was carefully removed. In some cases it became necessary to remove the rock as high as 12 ft. above the roof line, and though the contractor did not receive any payment for the excavation outside of the neat lines, he preferred to remove all loose and dangerous rock rather than attempt to hold it in place with timber. A powerful electric searchlight was kept on the job at all times, and examinations of the roof were made several times a week, all loose rock being removed.

The rock throughout this stretch was very poor, and, as very little timbering was used, it was necessary that the excavation be followed by the construction as soon as possible, for, though the roof was carefully scaled, the constant blasting loosened up the rock, so that it was inadvisable to leave it exposed and unsupported for any considerable length of time. Besides, the contractor was not permitted to widen the center excavation for the two tracks until the structure for the one track had been completed and the rock over it had been caught up, or to make the excavation for either local track on the side until the roof of the structure for the adjacent express track had been completed and the rock over it had been safely caught up.

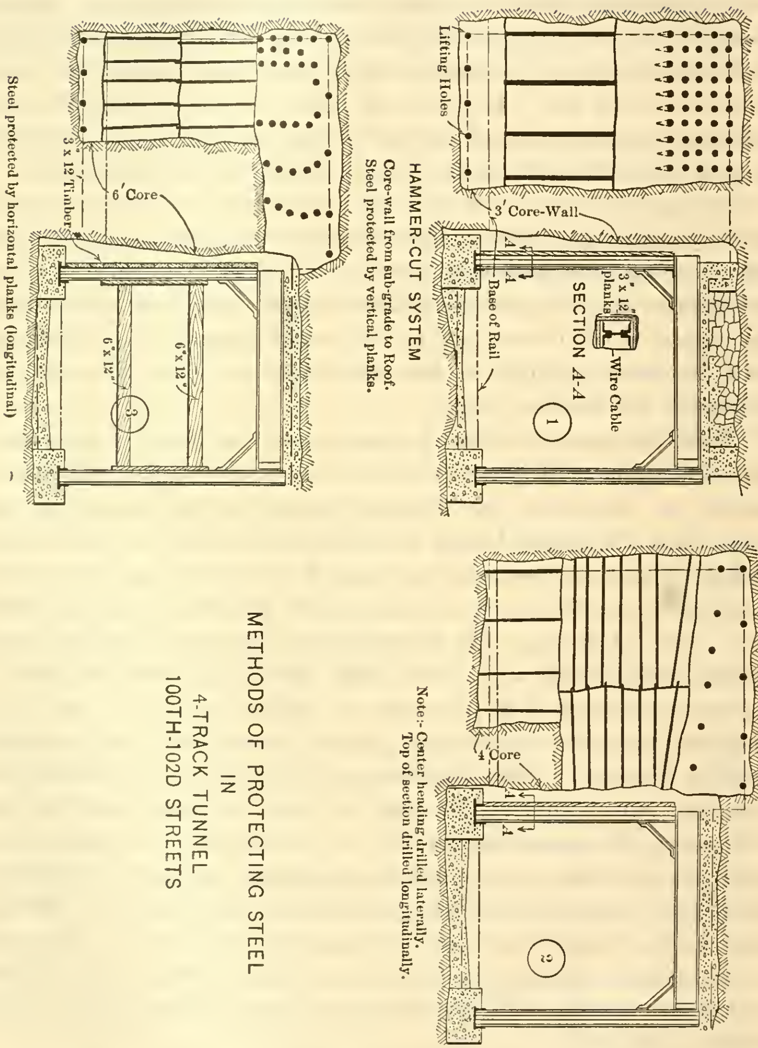
At first, the space over the roof was filled with hand-packed rock, but this proved unsatisfactory, for, when the excavation was made for the local tracks on the sides, the hand-packing was not sufficient to hold the rock core over the express tracks in place. Horizontal

seams started to develop in the core, and the voids in the hand-packing as well as the cracks in the rock core were then grouted with Portland cement grout to prevent bringing concentrated loads on the roof. After this, where the excess space was not too large, or where the rock was very poor, the roof concrete was carried solid to the rock above; where the rock broke very high, continuous longitudinal concrete walls, from 2 to 4 ft. thick, were built over each of the partition walls of the structure and carried solid to the rock above, and the space between the walls was filled with hand-packing (Plate IX).

No attempt was made to excavate for the local tracks on the sides until the adjacent express track structure had been completed and the overlying rock had been caught up. The plans called for an emergency exit to the surface at 100th Street, with a cross-drift over the express tracks connecting the two outside tracks. The contractor used this shaft and drift as working points from which to make the excavation for the local tracks.

While the excavation for the local tracks was being made north and south from 100th Street, work was also started at the 102d Street portal. At this point, the structure consists of four tracks on the same level, the tunnel having a cross-section of 60 by 17 ft. The rock as exposed at the portal was faulted and broken up, and it was clear that it would not be safe to excavate for more than one track at a time. (Fig. 18.) The excavation was first made for the west, outside (local) track, and carried south about 75 ft. from the portal. A cross-drift, about 20 ft. wide, was then carried to the east neat line, and the excavation for the east, outside (local) track was extended north to the portal. After the structure for this part of the excavation had been completed and the roof had been concreted solid to the rock above, the excavation for the two center tracks was made, but prior to this, and as an additional precaution against a movement of the rock over the portal, concrete buttress walls (about 3 ft. thick) were built up against the face of the portal, and rested on the roof of the finished structure in the open cut beyond the portal. Three buttress walls were built, one over each of the partition walls of the subway (Fig. 20).

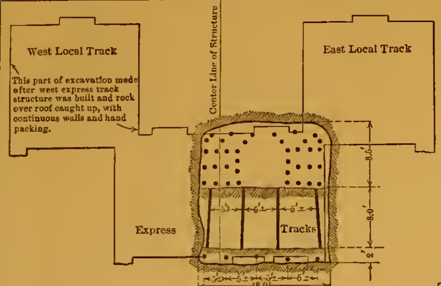
No special difficulties were encountered in making the excavation for the local tracks on the sides. Precautions, however, had to be taken to protect the adjacent finished structure (Fig. 22).



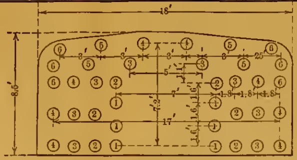
METHODS OF PROTECTING STEEL
IN
4-TRACK TUNNEL
100TH-102D STREETS

Fig. 22.

1

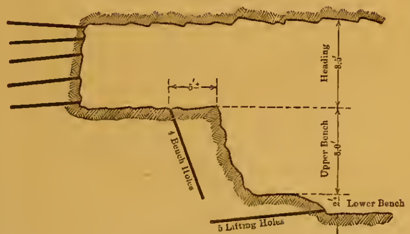


SECTION LOOKING NORTH



DRILLING DIAGRAM OF HEADING
SHOWING FIRING ORDER

LOADING DATA.							
Drill holes		Depth, in feet.	Total linear feet.	60% Forcite			
				Per hole.		Total pounds.	Pounds per foot.
No.	Description			Sticks	Pounds		
HEADING							
6	Dry holes.	7.5	45	6	3.4	20.4	0.45
6	Break-down.	7.5	45	6	3.4	20.4	0.45
8	Center cut.	9.5	76	9	5.0	40.0	0.53
18	Side.	7.5	135	7	3.9	70.2	0.52
—	Total for 7 ft. advance	—	301	—	—	151.0	0.50
UPPER BENCH							
4	Bench.	9	36	10	5.6	22.4	0.62
LOWER BENCH							
5	Lifting holes.	7	35	10	5.6	28.0	0.80

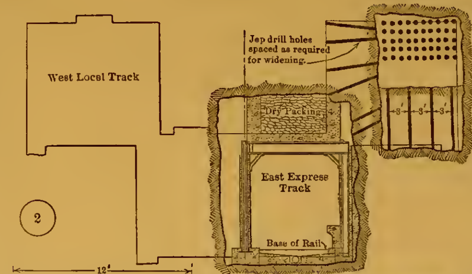


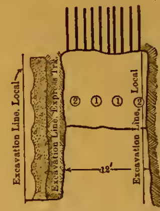
PROFILE
LOWER LEVEL HEADING

QUANTITIES FOR 7-FOOT ADVANCE.			
	Heading	Bench	Total
Yardage.	39.6	46.7	86.3
Total linear feet of holes.	301.0	85.0	386.0
Total pounds.	151.0	56.1	207.1
Linear feet of holes per cubic yard.	7.61	1.82	4.48
Pounds per cubic yards.	3.82	1.20	2.33

METHOD OF EXCAVATION
4-TRACK TUNNEL
100TH TO 102D STREETS.

2

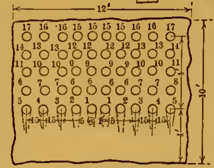




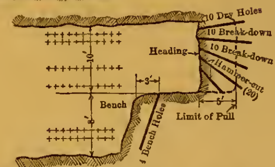
PLAN OF LOCAL TUNNEL

LOADING DATA.							
Drill holes		Depth, in feet.	Total linear feet.	60% Gelatin Dynamite			
				Per hole.		Total pounds.	Pounds per foot.
No.	Description			Sticks	Pounds		
HEADING							
15-17	Dry holes.	6.5	65	4	2.4	24	0.36
9-14	Break-down.	6.5	130	4	2.4	48	0.36
6-8	Hammer cut.	7.0	70	4	2.4	24	0.34
1-5	" "	4.5	45	2	1.2	12	0.26
	Total for 6 ft. pull		310			108	
BENCH							
1-2	Bench.	8.0	32	4	2.4	9.6	0.33
	Total for 3 ft. bench		32			10	
SIDE							
	Jap.	3 to 6	140	2	1.2	36	0.25
	Total for 6 ft. advance		504			160	

QUANTITIES FOR 6-FOOT ADVANCE			
	Yardage.	Linear feet of holes per cubic yard.	Pounds of 60% dynamite per cubic yard
Heading	22 ±	14.1	4.90
Bench	17 ±	3.2	0.94
Side	19 ±	7.4	1.90
Total	58 ±	8.7	2.76

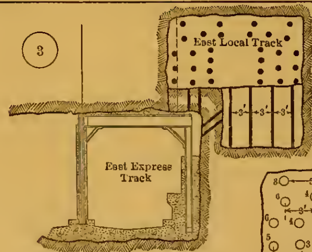


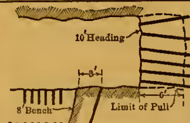
FIRING DIAGRAM
Showing Order of Firing Holes in Local Heading



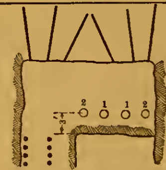
PROFILE OF LOCAL HEADING

3

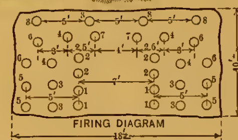




PROFILE
LOCAL TRACK



PLAN OF LOCAL TUNNEL



FIRING DIAGRAM

QUANTITIES FOR 6-FOOT ADVANCE			
	Yardage.	Linear feet of holes per cubic yard.	Pounds of 60% dynamite per cubic yard.
Heading	42	5.40	1.71
Bench	22	2.91	0.87
Side	11	7.64	2.61
Total	75	5.00	1.60

LOADING DATA.							
Drill holes		Depth, in feet.	Total linear feet.	60% Forcite			
				Per hole.		Total pounds.	Pounds per foot
No.	Description			Sticks	Pounds		
HEADING							
8	Center cut.	7.0	56	4	2.4	19.2	0.34
12	Side.	8.0	96	4	2.4	28.8	0.30
6	Break-down.	7.5	45	4	2.4	14.4	0.32
4	Dry	7.5	30	4	2.4	9.6	0.32
	Total		227			72.0	
BENCH							
4	Bench.	8.0	32	4	2.4	9.6	0.30
	Total for 8 ft. advance		32			9.6	
SIDE							
24	Jap	3 to 6	84	2	2.2	23.8	0.34
	Total for 6 ft. advance.		275			120	

FIG. 23.—EXCAVATION FOR LOCAL TRACKS IN FOUR-TRACK TUNNEL.

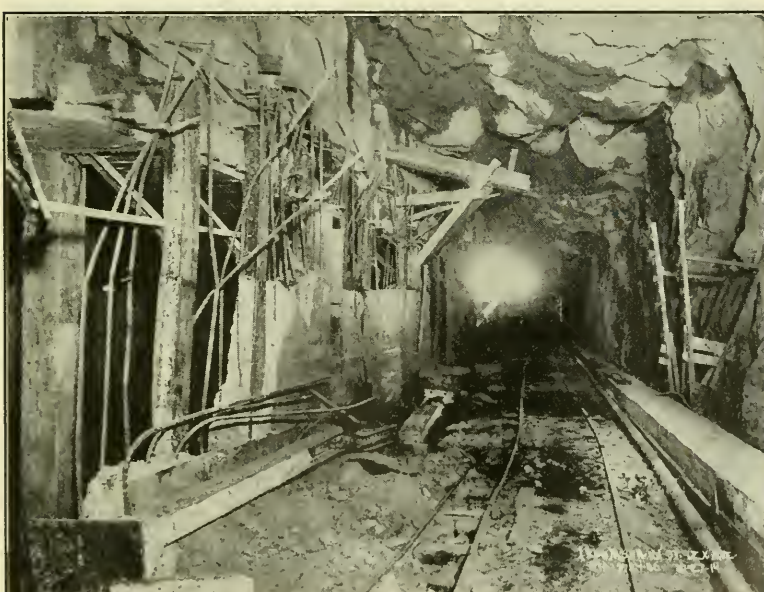


FIG. 24.—SUBWAY STRUCTURE DAMAGED BY BLASTING.

Fig. 25.—Damaged Columns Removed and Beams Supported by 12 by 12-In. Posts.

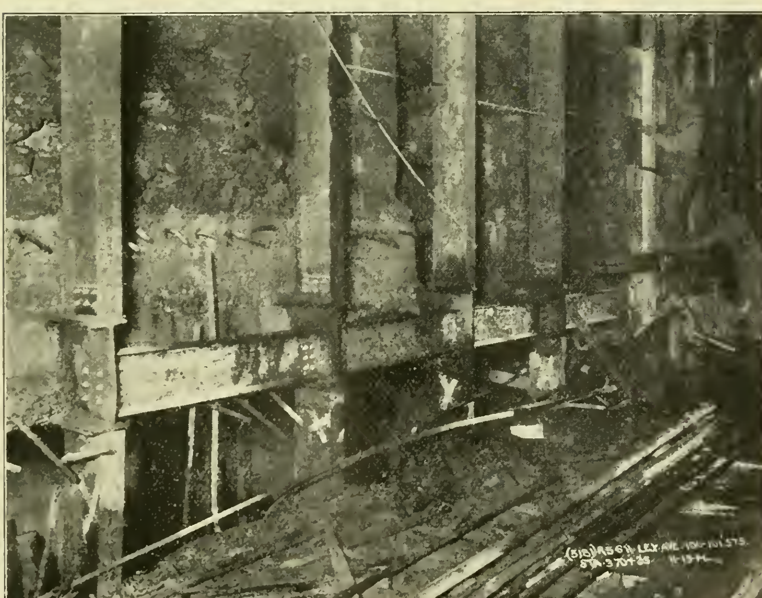


Fig. 26.—Beam Placed Between Roof Beams to Stiffen Them and Distribute the Load on the Side-Wall.

At first, the excavation for each local track was made as a separate tunnel, leaving a core-wall, from 3 to 4 ft. thick, between the excavation and the finished structure. The core-wall was kept about 25 ft. behind the heading, and was shattered so much by the adjacent blasting that it could be easily removed with little drilling and blasting. This method was soon abandoned, as considerable damage was done to the finished structure, by pieces of rock being blown against the columns during the blasting, and also by the rock of the core-wall being jammed against the columns. The columns were protected by timber planks, and, in some cases, by encasing them in the concrete partition walls called for by the plans. Though in some instances the concrete was injured by the blasting, the damage done to the structure was less serious than in the cases where concrete was not put in.

Very good results, as far as protecting the steel was concerned, were obtained by drilling the holes laterally and firing the rock away from the finished structure. Practically, this consisted of taking out a center heading and later removing the top of the section with breaking-down holes. When the bench was removed, a 4-ft. core-wall was left temporarily between the excavation and the finished structure. This method was soon abandoned, as its use generally required platforms or scaffolding on which to set up the drills.

The final and most successful method used was to place a continuous bulkhead of 3-in. planks between the steel and the rock to be excavated, and to brace the columns and partition wall over to the center wall with two 6 by 12-in. braces. The excavation was made with a small top heading and three benches, a 6-ft. core-wall being left temporarily between the bench and the columns. The core was really a part of the bench that had not been drilled, but it was shattered so much by the other blasting that it could be removed later with very little drilling and blasting (Fig. 23).

Considerable damage was done to the structure adjacent to which blasting was done (Fig. 24). The contractor was required to cut out and replace in a satisfactory manner about 200 ft. of 16-in. reinforced concrete wall and columns. Prior to removing the columns, the roof beams were posted up with 12 by 12-in. timbers to prevent any settlement (Fig. 25). In some cases the ends of the center track roof-beams were badly damaged as well as the columns, and it was not con-

sidered safe to attempt to remove them. In these cases a 12-in. I-beam was placed between the roof-beams to stiffen them and to distribute the load over the concrete wall instead of directly on the columns when the side-walls for the local track were placed (Fig. 26). In some cases, also, where jack-arches were used in the roof, they were badly damaged. As it was not considered safe to remove these arches and replace them, 6-in. cross-beams were introduced in the bottom of the arch and grouted, as shown in Fig. 27.

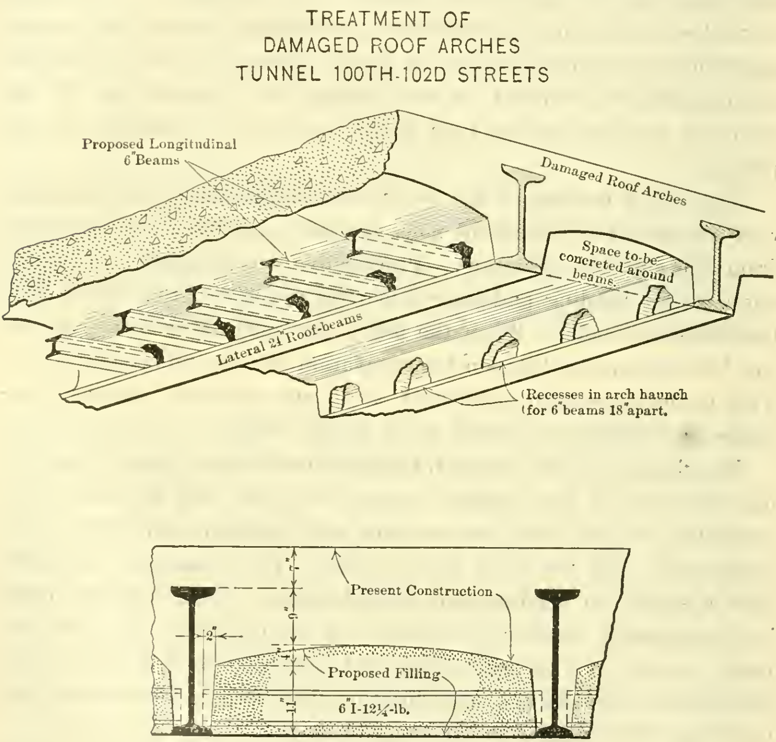


FIG. 27.

Some repair work was also necessary to the local track structures at 56th and 74th Streets, where they had settled on account of the excavation for the express track tunnel. North of 74th Street, considerable voids were found under the track floor. The ground at this point was a soft alluvial soil, and it did not seem likely that any satisfactory results could be obtained by grouting. Accordingly, the

contractor was ordered to re-build the footings under the columns and carry them down to the soil. The track floors were also re-built. South of 74th Street the void space was found under the floor for about 100 ft. of the structure, the voids in some cases being as great as 1 ft. The work in the express tunnel had drained the soil at this point so that it was compact and dry when repairs were to be made. Holes were placed in the local track floor about 10 ft. apart, and the voids were filled with grout. After this was done, investigating holes were again made through the floor and grout, and failed to disclose any void space. At 56th Street, when settlement began to take place, the contractor immediately grouted the space under the local track floor, and this did much toward checking the settlement. Later, when test holes were made through the local track floor, the grout, in some cases, was found to be 20 in. thick, and, as this rested on good soil, it was not necessary to make any material repairs, as it was possible to work up a new grade with the structure in its final location.

Handling of Muck.

In the work on Sections 8 and 9, the mucking was done by hand; on Sections 10 and 11, air shovels were used. The excavated material was loaded into large iron buckets, commonly known on the work as "battleships", and was not handled again until dumped into the scows for disposal. The flat-top trucks used were fitted with cradles to receive the bottom of the "battleships".

Plant.

The contractor's plant was operated by compressed air and electricity. The power-plant for the air was at 96th Street and East River. Electric current was furnished by the New York Edison Company.

Compressed-Air Plant.—The compressed-air plant consisted of five Ingersoll-Rand compressors, each with a capacity of 2 100 cu. ft. of free air per min.; five General Electric synchronous motors each of 350 h.p., 6 600 volts, and 24.7 amperes. Five receivers were used, two 6 by 18 ft., and three 5 by 15 ft. The air was brought to Lexington Avenue through 96th Street in a 10-in. pipe line. The pipe line was extended north and south of 96th Street to 53d and 106th Streets, and connections were made at the shafts as required. The air was com-

pressed to a pressure of 100 lb., and was delivered in the headings at about 90 lb.

Shovel.—Four 38-ton Marion shovels, Model No. 40, with 1-yd. buckets, were used on Sections 10 and 11. The shovels were provided with 18-ft. booms when working in the double-deck tunnels, but these were cut down to 15 ft. when the shovel was used in the single-deck tunnel.

Hoists.—The electric hoists used at the surface at the shafts were generally Lambert, direct-current, 60-h.p. 230 volts, and 220 amperes. The hoisting engines used below for hauling the mucking cars were Lambert 7 by 10-in. double-drum, and were operated by compressed air.

Electric Searchlight.—The electric searchlight, used in examining the roof of the tunnel before the lining had been placed, was made by the Rushmore Dynamo Works, being described as Type A, 110 volts, and 20 amperes.

Pumps.—In the tunnel, 6-in. Cameron suction pumps, operated by compressed air, were used to discharge the water into sumps, and from there the water was discharged into the sewers by electrically-operated centrifugal pumps.

"Battleships."—The "battleships", or buckets, were made of $\frac{1}{4}$-in. wrought iron, and were 4 ft. 8 in. by 7 ft. by 3 ft. 10 in. Their capacity was 4.6 cu. yd., water measure.

Drills and Columns.—Ingersoll-Rand 6-in. columns were used to drill the headings. The tripod drills used were generally Ingersoll-Rand, Type E-44 (with $3\frac{1}{4}$-in. cylinder), F-94 ($3\frac{5}{8}$-in. cylinder), and E-33 ($3\frac{1}{4}$-in. cylinder). A depth of about 2 ft. was drilled with each sharpening of the steel.

The extensive use of the tripod drills was probably due to the fact that, when this job started, the hammer type then on the market was not very efficient. The maximum length of steel that could be used with such drills at that time was 6 ft. Toward the close of the work, several new kinds of rotary hand-drills were put on the market, and these proved so satisfactory that they practically supplanted the heavier drills formerly used in this work. The first hand-drills used were the McKiernan-Terry non-rotating hand-drill, Style B. These were replaced later by the Ingersoll-Rand rotating hand drills, Type BCR No. 33 and BCR No. 430. The superiority of these small machines over the heavy tripod drills is shown by the fact

that they will drill, on an average, about 30 ft. per hour, and are now supplied with steels up to 12 ft. in length. The saving in labor and power has contributed to the success of these small drills. An ordinary tripod drill with a $3\frac{5}{8}$-in. cylinder requires, at 90 lb. pressure, 159 ft. of air, and must have a drill runner and a driller's helper to run it. The BCR No. 33 hand-drill, at the same pressure, requires 90 ft. of air, and can be run by a driller without a helper. The tripod drills require the steel to be changed every 2 ft.; but, with the BCR drill, from 6 to 8 ft. can be drilled without a change.

Drill Steel.—For the large drills, $1\frac{1}{4}$-in. octagonal steel was used; and for the small drills, $\frac{7}{8}$-in. hollow hexagonal steel. A set of steels for the large drills was made up as follows:

Length of steel.	Diameter of steel.
2 ft. 9 in.	3 in.
4 " 0 "	$2\frac{1}{2}$ "
6 " 0 "	$2\frac{1}{4}$ "
8 " 0 "	2 "
10 " 0 "	$1\frac{3}{4}$ "
12 " 0 "	$1\frac{5}{8}$ "
14 " 0 "	$1\frac{1}{2}$ "

Cost Data.

The following figures may be considered fairly accurate, as representing the cost of the various classes of work indicated:

Cost of excavation per cubic yard in double-deck tunnels, Sections 10 and 11; sound rock not requiring timbering; mucking done by air shovel.................... $5.00

Cost of tunnel excavation per cubic yard in sound rock tunnel, no timbering being used (two-track tunnel, Sections 8 and 9).............................. $7.00

Cost of tunnel excavation per cubic yard in unsound rock tunnels, requiring segmental timbering (two-track tunnels, Sections 8 and 9)........................... $10.00

Cost of tunnel excavation in compressed air work (10 to 16 lb.). Only top of heading excavated. Segmental timbering used (two-track tunnels, Sections 8 and 9).... $15.00

In computing the foregoing figures, the following scale of wages and general charges were assumed, the scale of wages being based on an 8-hour day:

Superintendent	$300.00	per month.
Tunnel foreman	200.00	" "
Heading foreman	5.00	per day.
Mucking foreman ...	4.00	" "
Drillers	3.68	" "
Driller's helper	2.00	" "
Cranesman	5.00	" "
Shovel runner	6.50	" "
Muckers	2.00	" "
Blacksmith	3.68	" "
Blacksmith's helper ..	2.00	" "
Electrician	4.80	" "
Electrician's helper ..	2.20	" "
Drill repairer	3.00	" "
Timekeeper	3.00	" "
Hoist runner	4.75	" "
Signalman	2.00	" "
Three-horse teams ...	9.00	" "
Master mechanic.....	5.00	" "
Team checker	3.00	" "
Powder	$0.14	per lb.
Dump	0.30	per cu. yd.
Plant running and depreciation	1.42	per cu. yd.*
Administration charges..	10%	of cost of labor and materials.

Concrete Lining.

The plans for the subway structure in the tunnel did not contemplate the placing of the concrete solid to rock in all cases. Where the structure had an arched roof, the side-walls were in all cases to be concreted solid to rock up to 2 ft. above the springing line of the arch. Where the rock was good and did not require any timbering during the progress of the excavation, the regular construction shown

* The figures for the Manhattan tunnels of the Pennsylvania Railroad are given in *Transactions*, Am. Soc. C. E., Vol. LXVIII, p. 192.

Fig. 28.—Longitudinal Concrete Walls Over Roof of Tunnel.

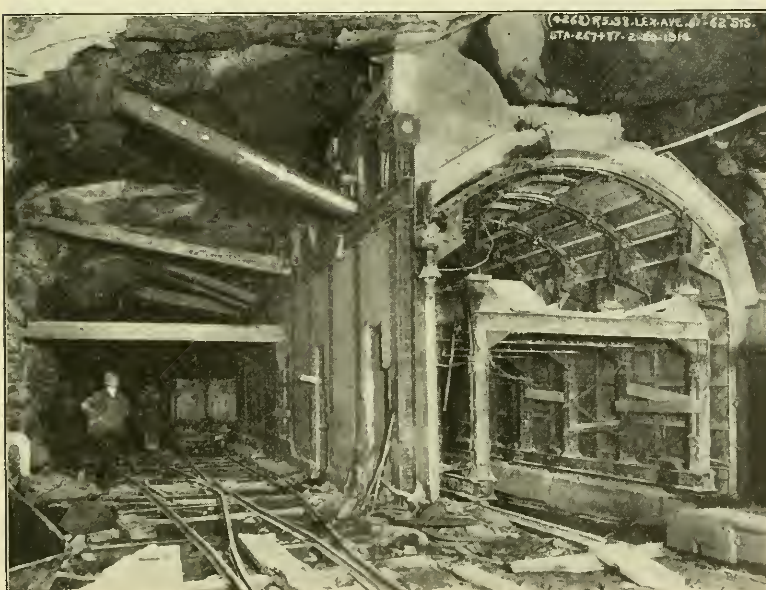


Fig. 29.—Blaw Forms Used in Concreting Express Tunnels.

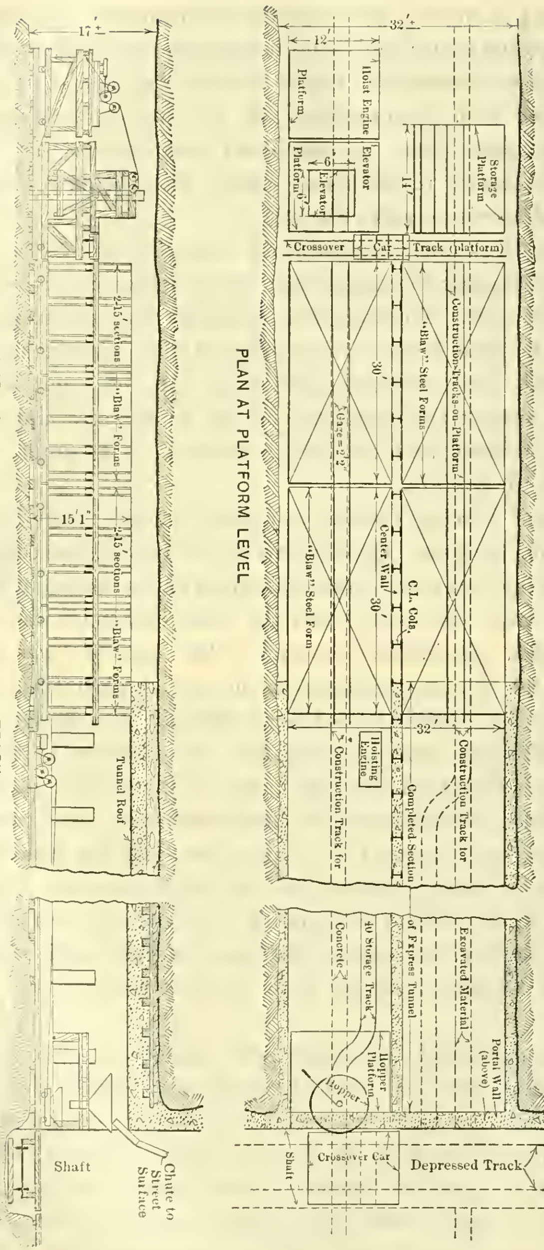
on the plans was put in, and a continuous concrete wall, 3 ft. thick, was built over the center wall, solid between the roof and the overlying rock. The space between the top of the side-wall and the center wall was then filled with hand-packing. In the tunnel, with four tracks on the same level, where the steel-bent construction was used, the structure was treated in the same manner, there being a longitudinal wall over each partition wall (Fig. 28).

Where the rock was unsound, and timbering had to be used for support while making the excavation, the structure was generally concreted solid to rock. To strengthen the timbering, the space between and back of the timber sets was first packed with concrete and grouted (Fig. 6), and, later, when the concrete lining was put in, it was placed solid against this concrete and the timber sets and the space between the timbers and the lining grouted. The grout used was generally a 1:1 mixture.

Mixing and Placing Concrete.—Central mixing plants were used on all the four sections. On Sections 8, 10, and 11, the concrete was mixed dry at the mixer, and water was added on the work; on Section 9, just enough water was used to wet the mass, and more was added on the work when considered necessary. The concrete was generally dumped on the roadway decking or on special platforms, and then transferred to the express tunnel below through iron chutes.

Several different methods of handling the concrete in the express tunnels were adopted on different parts of the work. The concrete cars were loaded directly from the chutes from the street surface. At first, the cars were dumped on a platform, and the concrete, after being passed by hand to several working platforms, was deposited in place. This crude method of handling concrete was soon abandoned, and various devices were used so that the concrete could be deposited directly on a working platform from which it could be shoveled into the forms.

On Section 8 (two-track tunnel), the common practice was to use a ramp leading from the floor of the express tunnel to a working platform. The cars were hauled to the platform, and the concrete was dumped and placed in the form by hand. Though this was an advance over the previous method, it was open to the serious objection that the ramps blocked the mucking tracks so that it was impossible to remove any muck while the concreting was being done.



LAYOUT OF CONTRACTOR'S PLANT FOR HANDLING CONCRETE
SECTION 9, EXPRESS TUNNEL

PLAN AT PLATFORM LEVEL

LONGITUDINAL SECTION ON C.L. OF EAST TRACK

FIG. 30.

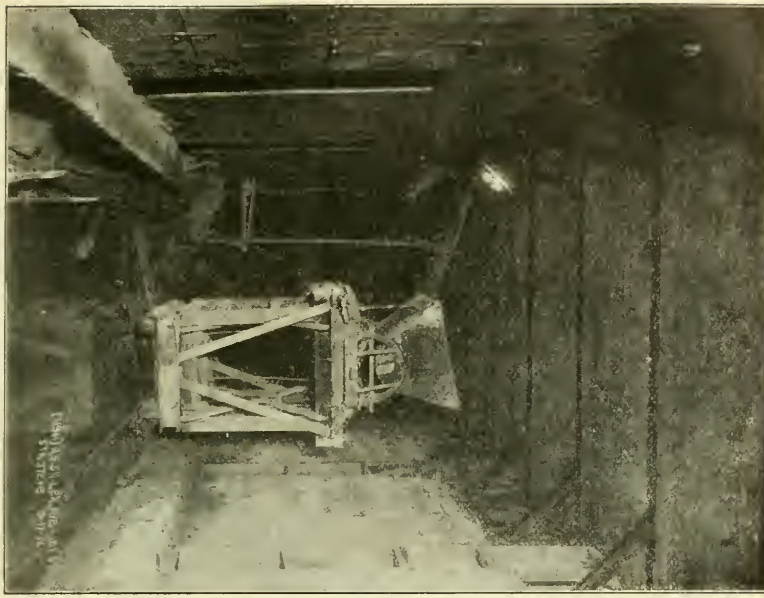


Fig. 31.—Method of Handling Concrete in Tunnel, Section 11.

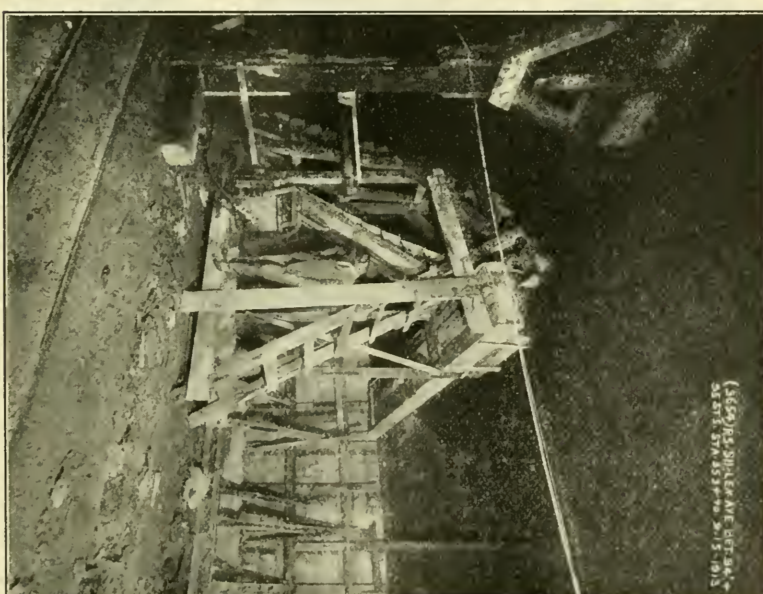


Fig. 32.—Continuous Traveler Used to Handle Concrete in Tunnel, Section 11.

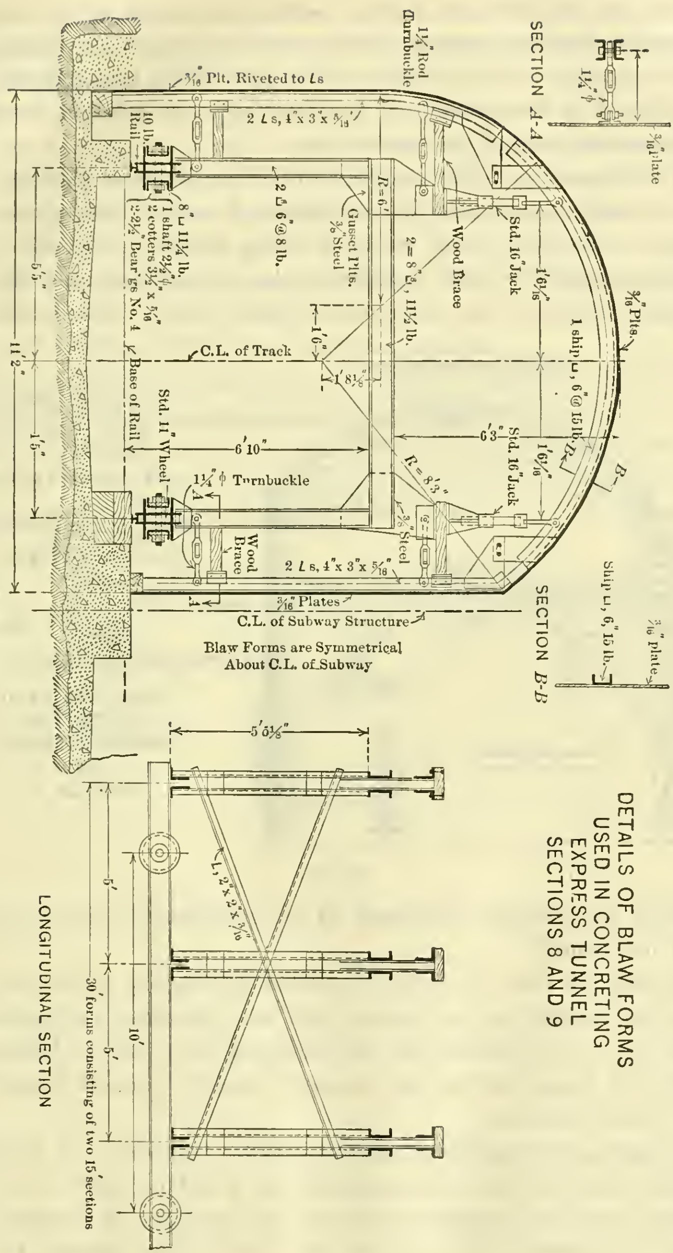

DETAILS OF BLAW FORMS
USED IN CONCRETING
EXPRESS TUNNEL
SECTIONS 8 AND 9
SECTION A-A
SECTION B-B
LONGITUDINAL SECTION
C.L. of Track
C.L. of Subway Structure
Blaw Forms are Symmetrical
About C.L. of Subway
Wood Brace
Std. 16" Jack
Std. 11" Wheel
1¼" ϕ Turnbuckle
1¼" Rod Turnbuckle
Base of Rail
30 forms consisting of two 15' sections

FIG. 33.

Where this objectionable feature became so serious as to interfere materially with the progress of the work, a continuous working platform was built from the chute to that part of the tunnel which was being lined, so that there were separate tracks on different levels for both the mucking and the concrete cars.

To dispense with the necessity of a long working platform and double tracks, the contractor on Section 9 used a lift to raise the concrete cars to the level of the working platform (Fig. 30). The latter was provided with transfer tracks, so that only one lift was necessary to raise the concrete for either arch. This method of

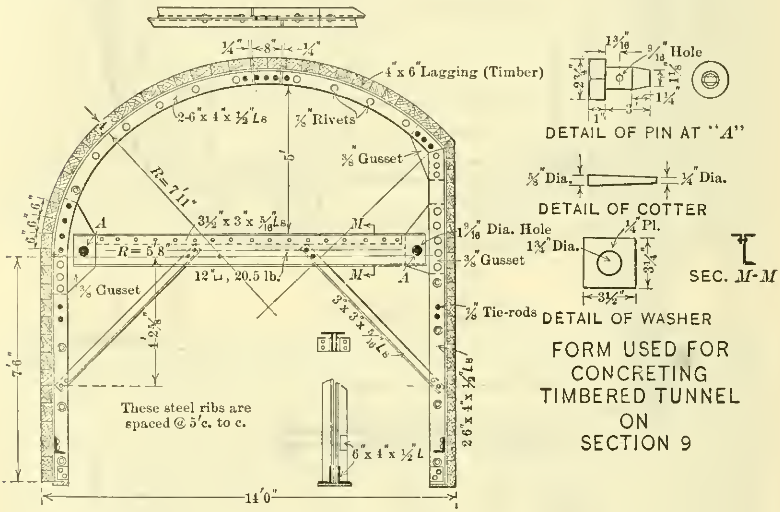


Fig. 34.

handling the concrete eliminated all the objectionable features previously mentioned.

Toward the close of the work, another satisfactory method of handling the concrete in the express levels was introduced on Section 11 (Fig. 31). The concrete car was mounted on a timber framework built on a flatcar, so that the concrete could be dumped directly on the working platform.

A continuous traveler or bucket elevator (Fig. 32) was tried for a short time, but was soon abandoned, as it did not prove very successful. The main objection was that the quantity of concrete that could be handled in this way was too small. The concrete for the

roof was deposited on the platform and then shoveled into the forms; the concrete for the side-walls was dumped in a sloping trough, leading into the forms.

Forms for Concreting.—Figs. 29 to 34 illustrate the principal types of forms used in concreting the express tunnels. Where the excavation was through sound rock which did not require any timbering, the general practice was to use the Blaw movable forms (Figs. 29 and 33). Where the tunnel excavation had to be timbered, the posts prevented the satisfactory use of the Blaw forms, it being impossible to move them. In these cases, forms of wood or those having steel ribs with longitudinal lagging were used (Fig. 34).

The tunnel work was started in April, 1912, and completed in December, 1914. The work was done under the supervision of the Public Service Commission for the First District, Alfred Craven, M. Am. Soc. C. E., Chief Engineer. The writer, as Assistant Division Engineer, was in charge of the construction described in this paper.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

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EARTH PRESSURES: A PRACTICAL COMPARISON OF THEORIES AND EXPERIMENTS.*

By L. D. Cornish, M. Am. Soc. C. E.

Synopsis.

Of all structures which the engineer of to-day is required to design for conditions of static loading, there is probably none which is so irritating as the ordinary retaining wall. This, of course, is due to the lack of definite and correct data relative to the pressures exerted by the various kinds of earthy materials and to the variety of formulas which have been proposed for determining the amount and direction of the resultant earth pressure which acts on a retaining wall.

The writer has studied with a great deal of interest all the books and papers he could obtain concerning earth pressure theories, and the formulas or graphical analyses derived therefrom. Such study has been confined principally to a comparison of solutions based on the Rankine theory with those based on the sliding-wedge theory, and certain facts were developed which appear to discredit, in certain particulars, these commonly accepted theories. It is quite probable that other investigators have observed at least some of the same results, but, as the writer had never seen them discussed, he thought

* This paper will not be presented at any meeting of the Society, but written communications on the subject are invited for subsequent publication in *Proceedings,* and with the paper in *Transactions*.

the matter of sufficient importance to assemble the results of his studies in this brief paper.

Frequent reference will be made to the theories and formulas as either those of Rankine or Cain. A reference to Rankine is intended to relate, not only to the theory and formulas for the special cases as advanced by Rankine, but also to the solutions, based on his theory, covering all cases of inclination of a wall, as developed and published by Milo S. Ketchum* and M. A. Howe,† Members, Am. Soc. C. E. A reference to Cain relates to the solution by William Cain, M. Am. Soc. C. E., of the wedge theory as given in his paper‡ and in Ketchum's book.

Formulas to express the resultant earth pressure, as derived from the two theories, are similar, and in some cases identical; but the direction of the resultant force is different in all cases, except for a wall with vertical back and with the angle of surcharge equal to the angle of internal friction. These formulas, particularly those involving surcharge, are somewhat complicated, and it is impossible to grasp mentally their entire significance relative to the dimensions of a wall to resist the forces indicated by them. The writer has endeavored to show graphically the results obtained in actual wall design by the use of the different formulas and by values obtained in certain experiments, so that the points of interest may be discussed without resorting to mathematics. To accomplish this, and to avoid complications in equations, due to uneconomical distribution of masonry in the walls, all wall sections discussed will be triangular and designed as to width so that the resultant of the external forces shall cut a horizontal plane of the wall at the outer edge of the middle third.

Nomenclature.—The nomenclature used in Figs. 1 to 15, and discussion thereof is that used by Cain in his paper discussing Leygue's experiments, and, for the remainder of this paper, is the same as that used by Ketchum in his "Walls, Bins, and Grain Elevators". The differences are few and should cause no confusion, and the use

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* "The Design of Walls, Bins, and Grain Elevators."

† "Retaining Walls for Earth."

‡ "Experiments on Retaining Walls and Pressures on Tunnels", *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 403.

of both will facilitate quick comparison with the works of the authors mentioned.

h = vertical height of wall;

ch = " " to center of pressure on AB, Fig. 1, $c = \frac{1}{3}$;

ph = width of base of wall;

p = ratio of base to height;

e = weight of earth per cubic foot (Cain-Leygue);

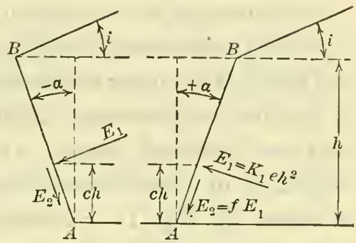


FIG. 1.

w = weight of earth per cubic foot (Ketchum);

W = total weight of earth per linear foot;

w_1 = weight of wall per cubic foot;

W_1 = total weight of wall per linear foot;

P = resultant earth pressure per linear foot of wall;

P_H and P_V = the horizontal and vertical components, respectively, of P;

$E_1 = K_1\, eh^2$ = normal component of P (Cain-Leygue);

$E_2 = E_1 \tan. \phi^1$ = component of P parallel to back of wall (Cain-Leygue);

k = cohesion, in pounds per square foot (Cain-Leygue);

K_1 = coefficient of E_1 (Cain-Leygue);

i = inclination of surface of earth to horizontal (Cain-Leygue);

δ = inclination of surface of earth to horizontal (Ketchum);

α = angle between back of wall and the vertical, counted as positive or negative, as in Fig. 12* (Cain-Leygue);

ϕ = angle of repose (internal friction) of the earth fill;

ϕ^1 = angle of friction of the earth filling on the back of the wall;

* Reproduced herein as Fig. 1.

$\theta =$ angle between the back of the wall and a horizontal line extending into the fill $= 90 + \alpha$;

$r = \dfrac{1 - \sin.\, \phi}{1 + \sin.\, \phi} =$ the Rankine ratio of horizontal to vertical earth pressures $= k$, as used by Ketchum.

In discussing his solution of the sliding-wedge theory, Cain refers to various experiments, among which are those made by Leygue* and in Table 3 of his paper before this Society.† Cain gives certain results of Leygue's experiments. Leygue's experiments were made with dry sand and retaining boards, *AB,* which could be rotated about the bottom, *A,* in order to produce any desired inclination to the vertical, as shown by Fig. 1. Suitable observations were taken and results obtained, from which the values of K_1, as given in the last column of Cain's Table 3, could be computed. The reader is referred to Cain's paper† for additional details.

The values of K_1 show the relative variation in the total normal thrust against walls under different conditions of loading and inclination of the back of the walls, but convey no immediate idea of the dimensions of the walls necessary to withstand such thrusts, and, after all, the dimensions are of most interest to the practical engineer or designer.

As a preliminary to the discussion of the formulas in common use, and to provide for subsequent comparison of designs based on theory with those based on experiments, retaining walls were designed to satisfy the experimental values of K_1, as given in the last column of Cain's Table 3. In designing the walls, the unit weight of earth, e, was assumed at 100 lb. per cu. ft., and the weight of wall, w, at 140 lb. per cu. ft. The resulting designs are shown by Figs. 2 to 8, and it may be noted that the values of e and h selected are such that $eh^2 = 10\,000$, and, consequently, the normal thrust, E_1, is 10 000 times K_1, or the significant figures of E_1 of the designs and of K_1 of Cain's Table 3 are the same.

The width of the base of the walls, ph, was computed from the equations for p shown for Figs. 2 to 15, which equations are condi-

* These experiments, with discussion thereon, may be found in *Annales des Ponts et Chaussées,* November, 1885.

† "Experiments on Retaining Walls and Pressures on Tunnels", *Transactions,* Am. Soc. C. E., Vol. LXXII, p. 403.

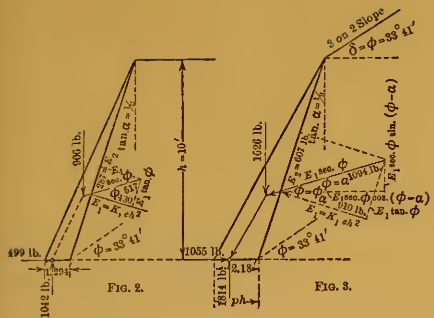


FIG. 2. FIG. 3.

For Figs. 2 and 3

Let $\tan.\alpha - 4K_1\frac{e}{w_1}\sec.\phi\,\sin.(\phi-\alpha) = A$

and

$2K_1\frac{e}{w_1}\sec.\phi\,[\sin.(\phi-\alpha)\tan.\alpha + \cos.(\phi-\alpha)] = B$

then

$p = \frac{A}{2} + \sqrt{(\frac{A}{2})^2 + B} - \tan.\alpha$

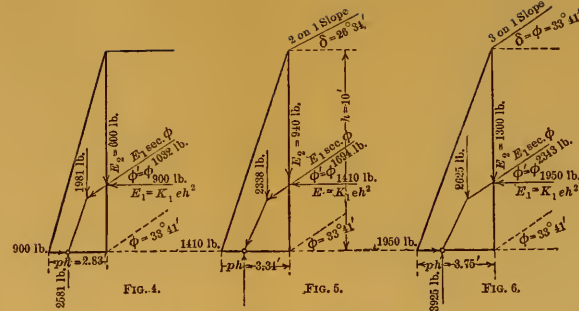


FIG. 4. FIG. 5. FIG. 6.

For Figs. 4, 5, and 6

$p = -2K_1\frac{e}{w_1}\tan.\phi + \sqrt{(2K_1\frac{e}{w_1}\tan.\phi)^2 + 2K_1\frac{e}{w_1}}$

Note:-
Figs. 2 to 8 derived from experimental K_1 of Table 3, of Cain's paper.

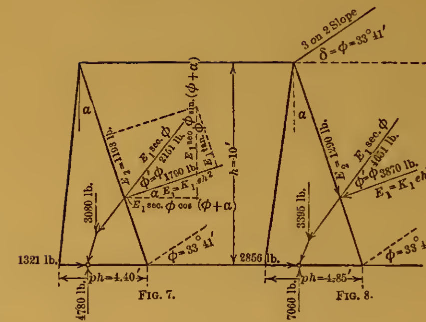


FIG. 7. FIG. 8.

For Figs. 7 and 8

Let $\tan.\alpha + 4K_1\frac{e}{w_1}\sec.\phi\,\sin.(\phi+\alpha) = A$

and

$2K_1\frac{e}{w_1}[2\sec.\phi\,\sin.(\phi+\alpha)\tan.\alpha - \sec.\alpha] = B$

then

$p = -\frac{A}{2} + \sqrt{(\frac{A}{2})^2 - B} + \tan.\alpha$

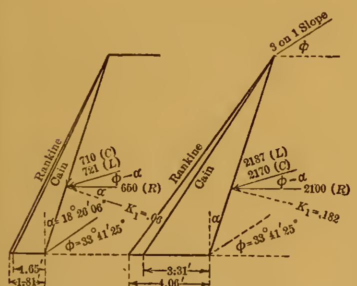


FIG. 9. FIG. 10.

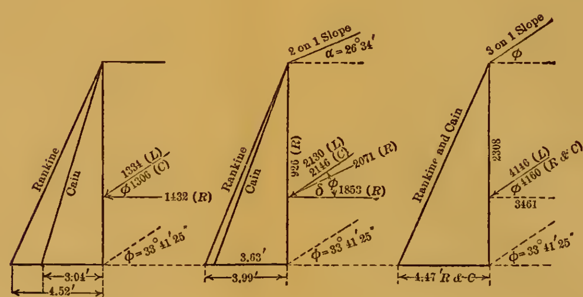


FIG. 11. FIG. 12. FIG. 13.

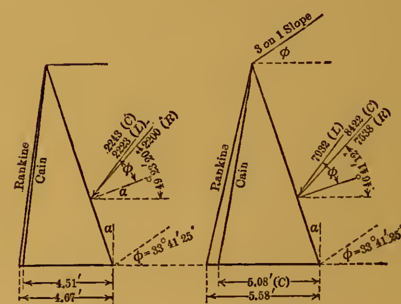


FIG. 14. FIG. 15.

Note: The letters C, R and L in parentheses indicate that the figures accompanying them were derived, respectively, from formulas of Cain Rankine (modified), and theoretical values of K, for $k=0$, as given in Table 3, of Cain's paper. The figures are shown for checking and comparison.

Figs. 9 to 15 Cain, or from Equations 36 to 43, Ketchum, page 49.
" 9 and 10 Rankine, from data 17j; Ketchum, page 35.
" 11 to 15 " " Equations 6, 8 and 8a, Ketchum.

tional on the resultant of all forces piercing the outer-third point, and the design was checked graphically as shown in the figures.

It may be noted that the required width of base steadily increases from Fig. 2 to Fig. 8. It is believed that any engineer, given these seven different cases at the same time and in a graphical form, would expect such a progressive increase, and that, in all cases, he would assert that an increase in the angle of surcharge, i, would require an increase in the width of the base. It is this point only which the foregoing discussion of Leygue's experiments is intended to emphasize for subsequent reference thereto.

In his paper, Cain showed that, in considering Leygue's experiments, the effect of cohesion should not be neglected, and, by graphical constructions and computations, he derives theoretical values of K_1, as given in the next to the last column of his Table 3 for assumed values of cohesion, k, as given in the third column of that table. It may be noted that the experimental values of K_1, as used in preparing Figs. 2 to 8, agree closely with the theoretical values, for k is equal to 1 lb. per sq. ft. Cohesion is usually neglected in practical designing, and, to show the effect of such neglect, walls, as shown by the smaller sections of Figs. 9 to 15, were designed for the theoretical values of K_1 corresponding to $k = 0$. All other assumptions were the same as those used for Figs. 2 to 8 and, therefore, the increase in section or base width is due entirely to the neglect of cohesion. The theoretical values of K_1 were derived by Cain from his theory; hence these are also the sections which result from the use of his formulas, and are marked for identification with his name. The base widths required for the same conditions were computed from the Rankine formulas, as modified by Ketchum or Howe, and the resulting sections are the larger ones marked Rankine in Figs. 9 to 15.

A study of these fourteen sections discloses three points of interest which warrant further investigation.

The first and most apparent point is the Rankine section of Fig. 12, which is smaller than the Rankine section of Fig. 11, although it is apparent by inspection that it should be larger on account of the 2:1 surcharge slope of the earth behind the wall. That it should be larger is proved by Leygue's experiments, as Fig. 5, with 2:1 surcharge, has a base 18% wider than Fig. 4, which has no surcharge. It

is also noted that the Rankine section, Fig. 13, for a 3 : 1 slope has a base about 1% less in width than the Rankine section of Fig. 11, which has no surcharge. These discrepancies between theory and experiment indicate that the formulas derived from the Rankine theory are erroneous, at least for certain conditions. This particular disagreement between theory on one side and reason and experiment on the other will doubtless be as surprising to many engineers as it was to the writer, and it will be discussed hereinafter in greater detail and for various conditions.

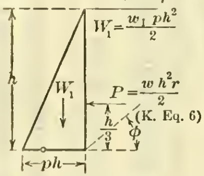
The second point of special interest is that, whereas the base of the experimental section, Fig. 4, is 30% wider than that of Fig. 3, yet the corresponding theoretical section, Fig. 11 (Cain), is 9% narrower than that of Fig. 10 (Cain). This indicates that, for walls with backs sloping toward the back-fill, the Cain and modified Rankine formulas give sections unnecessarily large. Walls of this kind are so unusual in practice that the writer, as yet, has made no further investigation of this case.

The third point is that the increase in base width of Figs. 14 and 15 (Cain) over that of Figs. 7 and 8 (Leygue), is much less than the corresponding increase for other comparable sections. This indicates that possibly the use of Cain's formulas for surcharged walls with a battered back results in sections only a little larger than for a case of no surcharge. Such is the case for walls with a vertical face and battered back, as will be shown hereinafter.

In order to put the formulas of Rankine and Cain in a comparable form, equations were deduced for p, the base width of triangular walls expressed as a percentage of the height. All the formulas for earth pressures as used are given by Ketchum,* and his nomenclature has been adopted for the following discussion in order to facilitate references.

The wall sections and equations are shown by Figs. 16 to 19 for the Rankine formulas, and by Figs. 20 to 23 for the Cain formulas. For the derivation of p, as shown, it is required that the resultant of all forces shall cut, and that the moments shall be taken about, the outer-third point of the base. The derivation of p for Figs. 16, 17, 18, and 20 is evident by inspection, as Figs. 17 and 20 require only the solving of the quadratic equation of moments.

* "The Design of Walls, Bins, and Grain Elevators."



$r=\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

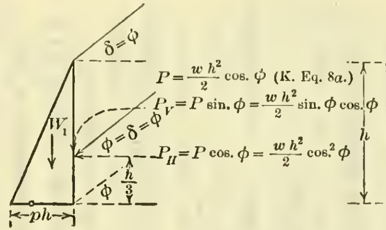
$W_1=\frac{w_1\,p h^2}{2}$

$P=\frac{w\,h^2 r}{2}$ (K. Eq. 6)

FIG. 16.

$$\frac{w_1 p^2 h^2}{6}=\frac{w\,h^3 r}{6}$$

whence $p=\sqrt{\frac{w\,r}{w_1}}$



$P=\frac{w\,h^2}{2}\cos.\phi$ (K. Eq. 8a.)

$P_V=P\sin.\phi=\frac{w\,h^2}{2}\sin.\phi\cos.\phi$

$P_H=P\cos.\phi=\frac{w\,h^2}{2}\cos.^2\phi$

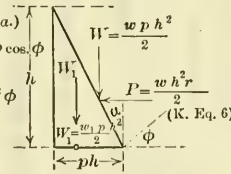
$\phi=\delta=\phi$, $\delta=\phi$

FIG. 17.

$$\frac{w_1 p^2 h^3}{6}+\frac{2\,w\,p\,h^3}{6}\sin.\phi\cos.\phi-\frac{w\,h^3}{6}\cos.^2\phi=0$$

whence

$$p=-\frac{w}{w_1}\sin.\phi\cos.\phi+\sqrt{(\tfrac{w}{w_1}\sin.\phi\cos.\phi)^2+\tfrac{w}{w_1}\cos.^2\phi}$$



$W=\frac{w\,p\,h^2}{2}$

$W_1=\frac{w_1\,p\,h^2}{2}$

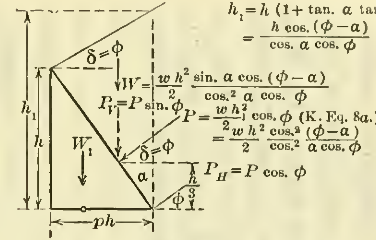
$P=\frac{w\,h^2 r}{2}$ (K. Eq. 6)

FIG. 18.

$$\frac{w\,p^2 h^3}{6}=\frac{w\,h^3 r}{6}$$

whence

$$p=\sqrt{r}$$



$h_1=h\,(1+\tan.\alpha\tan.\phi)$

$=\frac{h\cos.(\phi-\alpha)}{\cos.\alpha\cos.\phi}$

$W=\frac{w\,h^2}{2}\,\frac{\sin.\alpha\cos.(\phi-\alpha)}{\cos.^2\alpha\cos.\phi}$

$P_V=P\sin.\phi$

$P=\frac{w\,h_1^2}{2}\cos.\phi$ (K. Eq. 8a.)

$=\frac{w\,h^2}{2}\,\frac{\cos.^2(\phi-\alpha)}{\cos.^2\alpha\cos.\phi}$

$P_H=P\cos.\phi$

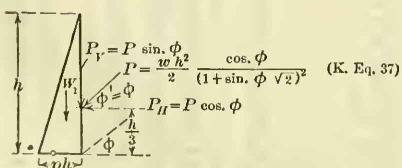
$\delta=\phi$

FIG. 19.

Let M = moment of a force, so that $M\,P_V$ may be read as the moment of force, P_V. Then $M\,W+M\,P_V-MP_H=0$, and, by substitution and reduction,

$$p=\sqrt{\frac{1-\sin.^2\phi}{1+\sin.^2\phi}}$$

Notes:- Figs. 16 to 19 accord with Rankine Theory.
" 20 to 23 " " Cain Theory.
Moments are taken about ⊖, and it is required that the resultant of all forces pass through ⊖
The width of bases: ph, are drawn to same scale for assumption that $\phi=33°41'25"$.
(K. Eq.—) refers to the numbered equations in Ketchum's "Walls, Bins and Grain Elevators."



$P_V=P\sin.\phi$

$P=\frac{w\,h^2}{2}\,\frac{\cos.\phi}{(1+\sin.\phi\sqrt{2})^2}$ (K. Eq. 37)

$\phi'=\phi$

$P_H=P\cos.\phi$

FIG. 20.

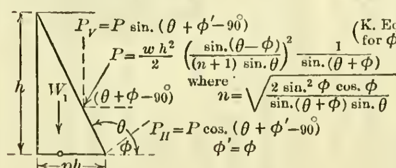
$$\frac{w_1 p^2 h^3}{6}+\frac{2\,w\,p\,h^3}{6}\,\frac{\sin.\phi\cos.\phi}{(1+\sin.\phi\sqrt{2})^2}-\frac{w\,h^3}{6}\,\frac{\cos.^2\phi}{(1+\sin.\phi\sqrt{2})^2}$$

whence

$$p=-\frac{w}{w_1}\,\frac{\sin.\phi\cos.\phi}{(1+\sin.\phi\sqrt{2})^2}+\sqrt{\left(\frac{w}{w_1}\,\frac{\sin.\phi\cos.\phi}{(1+\sin.\phi\sqrt{2})^2}\right)^2+\frac{w}{w_1}\,\frac{\cos.^2\phi}{(1+\sin.\phi\sqrt{2})^2}}$$

FIG. 21.

This figure and equations are identical with those for Fig. 17.



$P_V=P\sin.(\theta+\phi'-90°)$

$P=\frac{w\,h^2}{2}\left(\frac{\sin.(\theta-\phi)}{(n+1)\sin.\theta}\right)^2\frac{1}{\sin.(\theta+\phi)}$ (K. Eq. 42 for $\phi'=0$)

where $n=\sqrt{\frac{2\sin.^2\phi\cos.\phi}{\sin.(\theta+\phi)\sin.\theta}}$

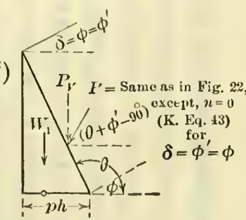
$(\theta+\phi-90°)$

$P_H=P\cos.(\theta+\phi'-90°)$

$\phi'=\phi$

FIG. 22.

Similarly as for Fig. 19
$MP_V-MP_H=0$
whence it may be shown that $p=\sqrt{r}$ or the same as for Fig. 18



$\delta=\phi=\phi'$

P_V P = Same as in Fig. 22, except, $n=0$ (K. Eq. 43) for, $\delta=\phi'=\phi$

$(\theta+\phi'-90°)$

FIG. 23.

Similarly as for Fig. 22 it may be shown that
$p=\sqrt{r}$

For Fig. 19, the earth thrust, P, against the wall is the same as the thrust against the vertical plane, bc, of height, h_1. The height, $h_1 = h + h \tan.\ \alpha \tan.\ \phi$

$$= h \frac{(\cos.\ \phi \cos.\ \alpha + \sin.\ \phi \sin.\ \alpha)}{\cos.\ \phi \cos.\ \alpha} = \frac{h \cos.\ (\phi - \alpha)}{\cos.\ \phi \cos.\ \alpha}$$

By substituting this value of h_1, the equations shown on Fig. 19 are obtained, which equations are in a convenient form for practical problems.

It is somewhat easier to derive p by substituting for h_1 its value, $h\ (1 + \tan.\ \alpha \tan.\ \phi)$.

The equation of moments now becomes,

$$\frac{wh^3}{6}\Big[\sin.\ \phi \cos.\ \phi\,(1 + \tan.\ \alpha \tan.\ \phi)^2 \tan.\ \alpha + (1 + \tan.\ \alpha \tan.\ \phi) \tan.^2\ \alpha$$
$$- \cos.^2\ \phi\ (1 + \tan.\ \alpha \tan.\ \phi)^2\Big] = 0;$$

whence $$\tan.^2\ \alpha\ (1 + \sin.^2\ \phi) - \cos.^2\ \phi = 0\ ;$$

$$\text{and } \tan\ \alpha = \sqrt{\frac{1 - \sin.^2\ \phi}{1 + \sin.^2\ \phi}} = p.$$

For Fig. 22, the equation of moments is,

$$P \sin.\ (\theta + \phi - 90)\ \frac{h \tan.\ (\theta - 90)}{3} = P \cos.\ (\theta + \phi - 90)\ \frac{h}{3};$$

whence $$\tan.\ (\theta - 90) = \cot.\ (\theta + \phi - 90) = p\ ;$$

or $$\cot.\ \theta = \tan.\ (\theta + \phi);$$

and $$\cot.\ \theta - \tan.\ \theta - 2 \tan.\ \phi = 0\ ;$$

but, $$\cot.\ \theta = -p\ ;$$

therefore, $$p^2 + 2\,p \tan.\ \phi - 1 = 0\ ;$$

whence, $$p = -\tan.\ \phi + \sqrt{\tan.^2\ \phi + 1}$$

$$= \sqrt{\frac{1 - \sin.\ \phi}{1 + \sin.\ \phi}} = \sqrt{r},$$

which is the same as for Rankine Fig. 18. It also may be shown that P_H and P_V (Cain) are equal in amount to P and W, as shown in Fig. 18.

For Fig. 23 it may be shown in a similar way that $p = \sqrt{r}$, but, in this case, P_H and P_V are greater in amount than for the similar forces of Fig. 22. (They are four times as great when $\phi = 30°$.) Therefore, an analysis of Fig. 23 shows that the surcharge merely produces greater compressive stresses in the wall, and the equations for p

indicate that surcharging a wall does not increase its tendency to overturn so long as the unit compression stress remains within safe limits. Such an indication is so contrary to one's preconceived ideas of the effect of surcharge that the theory from which it results can scarcely be accepted until it is substantiated by experimental proof.

It may be noted that for Figs. 18, 19, 22, and 23, the equations for p show that the width of the base is independent of the weight of either the wall or the back-fill.

The equations for Figs. 16 and 17 give identical values of p for $\frac{w}{w_1} = \frac{100}{140}$ and $\phi = 0°, 30°$, or $90°$; but p for Fig. 17 is the lesser for values of ϕ between 30° and 90° and greater for values less than 30°, although the difference is not marked, as will be shown hereinafter. The narrow base resulting from the Rankine surcharge formula is due to the assumption that the resultant earth thrust is parallel to the inclined surface, as this assumption introduces a vertical component which produces a resisting moment sufficient to balance the excess overturning moment due to the surcharge. This virtually means the assumption of frictional resistance on the back of the wall, an assumption which Cain makes for all cases in his solution of the sliding-wedge theory.

The figures and equations for p on Figs. 16 to 23 show inadequately the inconsistencies of both theories when applied to various cases, but they show that neither theory gives results for surcharged walls which accord with the inference drawn from wall failures or from the experiments of Leygue, namely, that for any type of wall, if the surcharge is increased, the section must also be increased, provided the walls must satisfy the requirement that the resultant shall cut the outer-third point, or any other common point within the base.

The difference between the cases shown by Figs 16 to 23 is shown more clearly by Fig. 24, on which the p curves are plotted with reference to the rectangular co-ordinates, ϕ and p. The reference numbers on the curves refer to Figs. 16 to 23. The equations of the curves are either shown or reference is made to Figs. 16 to 23 on which they may be found, and for all equations including the weight of the wall and the earth, it was assumed that $\frac{w}{w_1} = \frac{100}{140}$.

Curves 1 to 8 of Fig. 24 show the differences between the Rankine and Cain formulas and also between the formulas for the extreme conditions of no surcharge and maximum surcharge, but give no indication of the peculiar results obtained by the Rankine formula for Fig. 12 which is so much smaller than the corresponding wall, Fig. 11, which is not surcharged. This, however, is shown by the curves, $2a$ and $2b$, in the equations for which ϕ is a constant and δ a variable between the limits, zero and ϕ. These curves indicate that

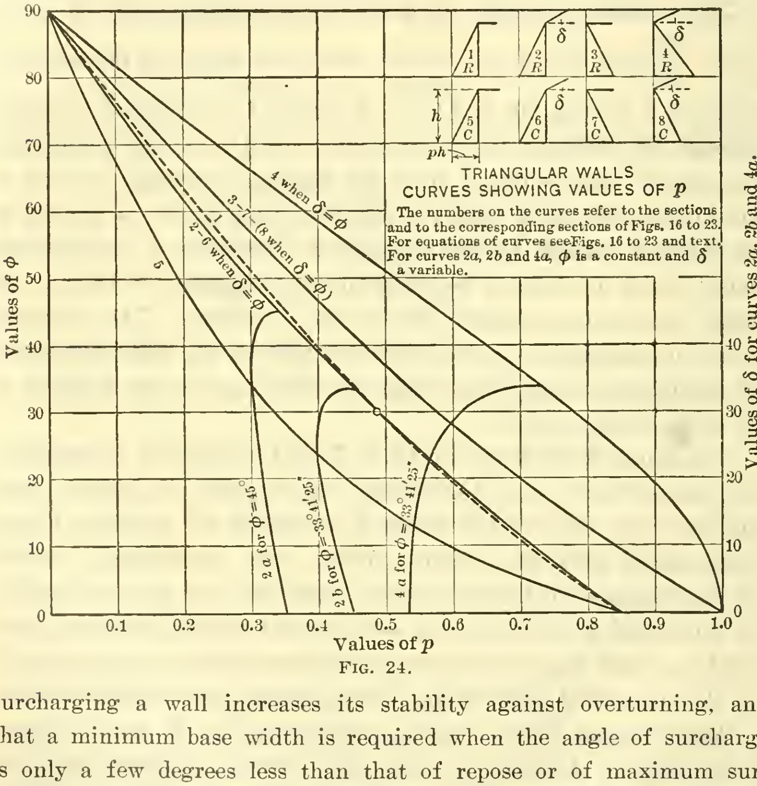


FIG. 24.

surcharging a wall increases its stability against overturning, and that a minimum base width is required when the angle of surcharge is only a few degrees less than that of repose or of maximum surcharge. Curve $4a$ has no minimum for finite values of δ, but is similar to the others in indicating a rapid decrease in p for small decreases in δ from its maximum value of ϕ.

The equations of Curves $2a$, $2b$, and $4a$ are as follows:

Let $A = \cos.\,\delta \dfrac{\cos.\,\delta - \sqrt{\cos.^2\delta - \cos.^2\phi}}{\cos.\,\delta + \sqrt{\cos.^2\delta - \cos.^2\phi}}$, ($K$. Equation 8), in

which ϕ is a constant; then for $2a$ and $2b$,

$$p = -\frac{w}{w_1} A \sin. \delta + \sqrt{\left(\frac{w}{w_1} A \sin. \delta\right)^2 + \frac{w}{w_1} A \cos. \delta};$$

and for Curve $4a$,

$$p = \sqrt{\frac{A \cos. \delta}{1 + A \tan. \delta \sin. \delta}}.$$

It is obvious that inferences, relative to surcharged earth pressure, to be drawn from Curves $2a$, $2b$, and $4a$, and from the similarity of Curves 1 and 2-6, are fallacious, and that, consequently, the Rankine theory—that the resultant earth thrust is parallel to the inclined surface of surcharge—is erroneous.

The writer has never been able to find or think of any good reason for assuming that the slope of surcharge should govern the slope of the resultant earth thrust for great depths, but will refrain from discussing it, as it is not the object of this paper to present a theoretical discussion, but to show, in as practical a way as the writer could devise, the results obtained from the application of the two principal existing theories.

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PAPERS AND DISCUSSIONS

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UNDERPINNING TRINITY VESTRY BUILDING FOR SUBWAY CONSTRUCTION

By H. de B. Parsons, M. Am. Soc. C. E.

To be Presented October 4th, 1916.

Synopsis.

This paper describes the underpinning of the Vestry and School Building of the Corporation of Trinity Church, which was made necessary by subway construction.

The building is on Church Street, between Fulton and Vesey Streets, Borough of Manhattan, New York. It is a brick structure with thick walls, having four floors, basement, and part attic, and was constructed about 30 years ago.

The Church Street subway curves at Fulton Street and passes beneath the building and beneath the Churchyard of St. Paul's Chapel to Vesey Street. The subway structure consists of two circular tunnels, each 20 ft. in diameter. The tops of these tunnels are just beneath the level of the footing stones of the building. As the tunnels run diagonally beneath the building, it was necessary to remove its original foundations entirely, to construct new foundation piers, and to transfer the load of the building to these new piers by means of cross-girders.

The paper describes how this work was done, and how the new

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings,* and, when finally closed, the papers, with discussion in full, will be published in *Transactions.*

foundation piers were sunk so as to cause the least disturbance to graves and vaults.

The brick walls of the building were first strengthened by fastening to them heavy lattice girders on each side, and, on the Fulton Street face fastening two 60-in. plate girders in a similar manner.

Excavations for the new underpinning piers were made at selected intervals, so that the settlement of the building could be kept under control.

The paper describes the use of concrete underpinning piles, and gives the results of a number of tests made to determine their bearing capacities. These tests showed that the piles had a tendency to rebound when pressure was relieved, and the paper describes how this element of weakness is overcome when such piles are used for underpinning.

The method of tunneling through the sand beneath the Churchyard and building is described.

Surveys were made before the work was undertaken and after it was finished, and these showed that the subway construction work caused the building to settle approximately 2 in., which was fairly uniform on account of the manner in which the underpinning piers were sunk.

The contract price for 1 000 ft. of this subway construction work was $982 740. The work commenced in June, 1913. Both tunnels were completed in June, 1914. The basement floor of the building was restored to the owners by October, 1914. The final restoration of the whole property was practically finished in April, 1916.

As the underpinning of the Vestry and School Building of the Corporation of Trinity Church was an unique example of protection work, made necessary by subway construction in New York City, the writer presents the following description which he hopes will be found of interest by many.

The chief features of this underpinning were the entire removal of the original foundations, the construction of new foundation piers to an elevation below the sub-grade of the tunnels, and the transference of the load of the building to these new piers, without interfering with its occupancy or use.

FIG. 1.—GENERAL VIEW OF TRINITY VESTRY BUILDING AND ST. PAUL'S CHURCHYARD.

FIG. 2.—LONGITUDINAL LATTICE GIRDER BEING ERECTED AND FASTENED IN PLACE.

The building is on the west side of St. Paul's Churchyard, and faces on Church Street between Fulton and Vesey Streets. Fig. 1 is a general view of the building, which shows clearly its chief characteristics and the proximity of the Churchyard, with its graves and vaults.

The building is of brick, having four floors, basement, and a part attic. It has a gabled roof, with side gables, or dormers, all having slopes of 45 degrees. The walls are 2 ft. thick above the water-table, and 2 ft. 9 in. below that level. The floor-beams are supported on the outside walls. In addition to these outside walls, about 100 ft. of interior walls also carry weight. The floors are surfaced with wooden or mosaic flooring, according to the use of the various rooms. The building is of heavy construction, and was completed about 30 years ago.

The subway, known as Route 5, was designed to run north on Church Street as far as Fulton Street, then to curve eastward beneath the Vestry Building and the Churchyard to Vesey Street, and then to curve again to the northward into Broadway. A special agreement was entered into between the Vestry of Trinity Church and the Public Service Commission, representing the City of New York, whereby the Vestry gave the City, under certain restrictions, a right of way for the purpose of constructing tunnels for a rapid transit railway beneath the Church property. The right of way was deeded to the City, as the Vestry realized that this subway work was part of a great municipal improvement.

The City was given possession of the basement for 18 months, so as to facilitate the work of construction, and agreed to build new foundations capable of carrying a new building of eight stories or one of lighter construction not exceeding ten stories.

Fig. 3 is a plan of the building, and shows the positions of the east and west tunnels beneath the building and the proportion of the foundations cut away by them. The tops of these tunnels were just beneath the level of the footing stones under the building walls, as shown in Fig. 4.

An examination of the building was made before any work was done; its condition was carefully noted, and all defects or cracks were recorded. Survey marks were made at various places around the exterior walls, and their elevations taken.

The following are the dimensions of the building:

Length on Church Street	164 ft. 0 in.
Width on Fulton Street	35 ft. 0 in.
Width on Vesey Street	48 ft. 0 in.
Length of exterior walls	428 ft. 0 in.
Area of ground plan	6 055 sq. ft.
Area of one floor (less walls)	5 340 sq. ft.

The following are the estimated weights:

Exterior walls	7 950 000 lb.	= 3 975	tons.
Interior walls and partitions	994 000 "	= 497	"
Floors	773 000 "	= 386.5	"
Plastering, ceilings and walls	797 000 "	= 398.5	"
Roof construction	393 000 "	= 196.5	"
Equipment, trim, plumbing, etc.	501 000 "	= 250.5	"
Live load, maximum	1 378 000 "	= 689	"
Total weight on foundations,	12 786 000 lb.	= 6 393	tons.

The area of the original foundations was:

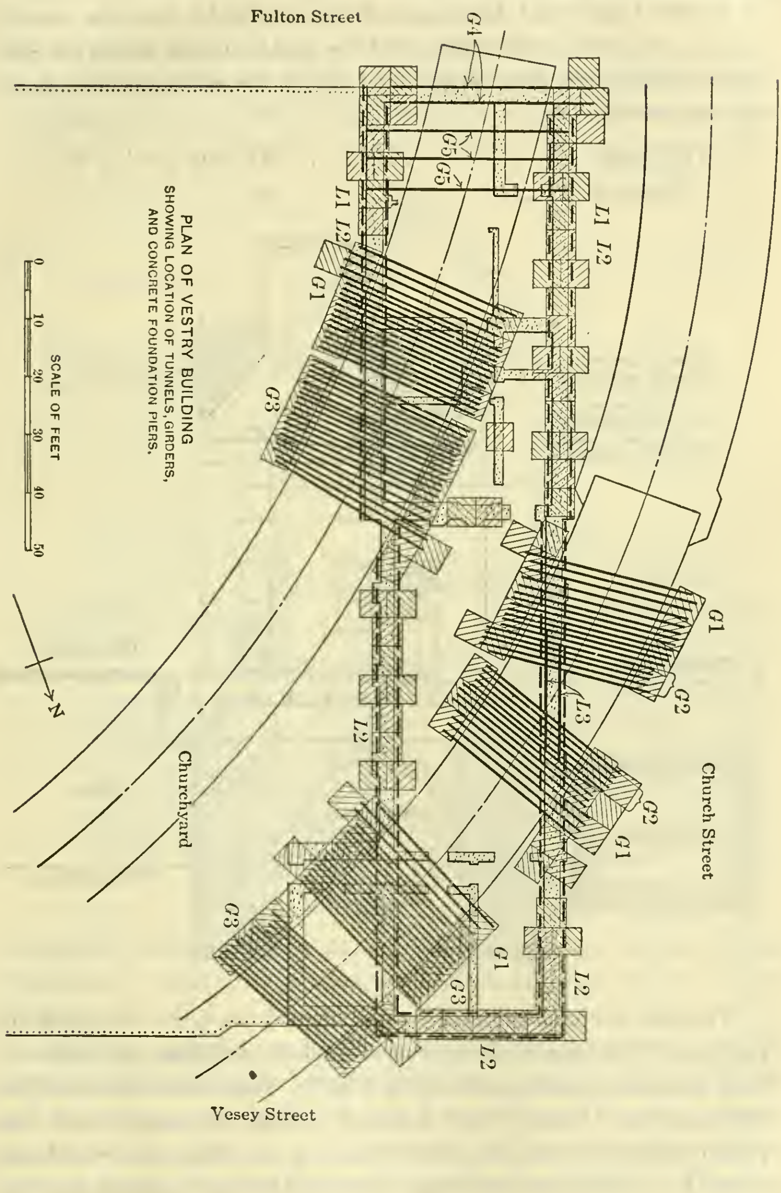
Under exterior walls	2 140 sq. ft.
Under interior weight-bearing walls	400 " "
Total area of foundations	2 540 sq. ft.

The unit loading on the original foundations, assuming the weight to be distributed uniformly over the footings, therefore, was 2.51 tons per sq. ft.

The soil was sand, varying in places from fine to moderately coarse. Mean high water level was 23 ft. below the street, but the ground-water was found about 4 ft. 6 in. above that level. Pumping in the adjacent subway excavations reduced the ground-water to about high water.

After conferences, the City agreed that the new foundations should be able to support the building if four new stories of similar construction were added, or their equivalent in weight. These additional floors were estimated at 3 907 tons.

Original weight of building	6 393 tons.
Additional weight, agreed upon	3 907 "
Estimated load for new foundations	10 300 tons.



PLAN OF VESTRY BUILDING
SHOWING LOCATION OF TUNNELS, GIRDERS,
AND CONCRETE FOUNDATION PIERS.

FIG. 3.

This estimated load on the exterior walls (10 300 tons divided by 428) equals 24 tons per lin. ft.

As the load would be supported principally by the side exterior walls, it was arbitrarily agreed that the underpinning under the side-walls should carry more weight and under the end-walls less weight than the average; or

End-walls	12 tons per lin. ft.
Side-walls.	28 " " " "

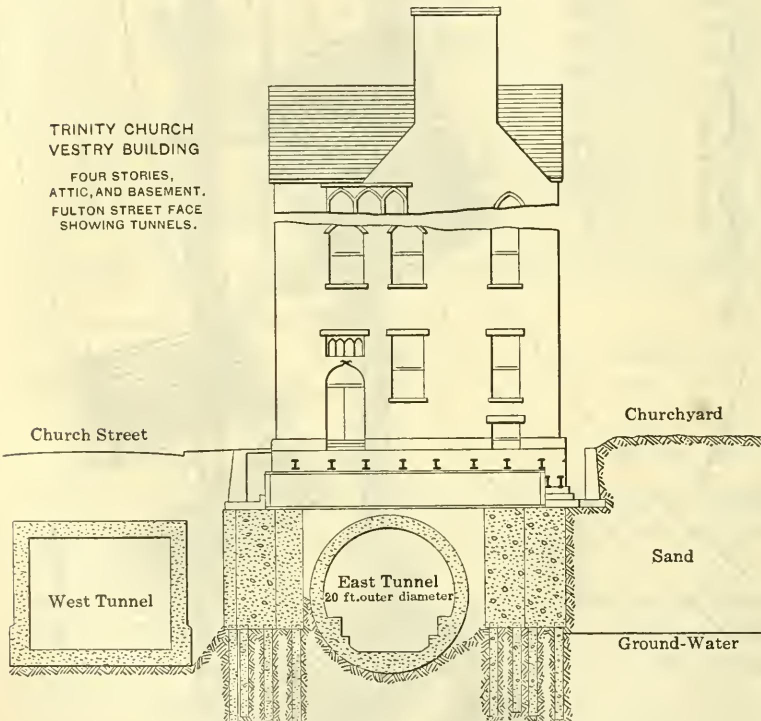


FIG. 4.

The plan for underpinning finally adopted consisted of sinking 115 pits, each 5 ft. square, under and around the building, but placed so as to clear the tunnels, as shown in Fig. 3. These pits were then filled with concrete. Girders were designed to span the tunnels, and were placed across the concrete piers in such a way that they would pass under the walls of the building. The load of the building was then

gradually transferred to these piers, or to the girders and by them to the piers. This plan will be better comprehended by referring to Fig. 4. which is a section at the Fulton Street face, and Fig. 5, which is a section through the building at about mid-length.

In Fig. 4, the west tunnel is under Church Street, clear of the building, and has reverted to the standard rectangular section. The east tunnel is just emerging from the building. It then changes to a

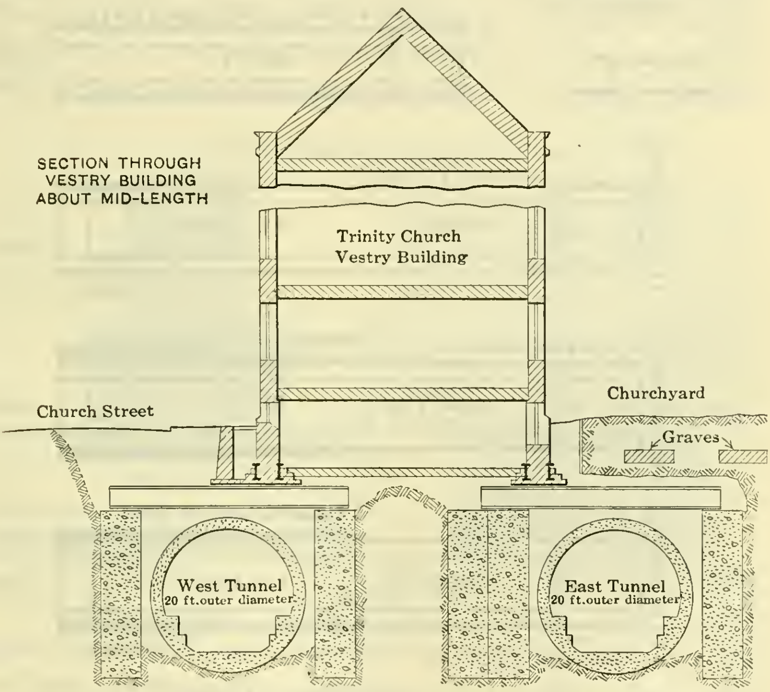


Fig. 5.

rectangular section, and unites with the west tunnel. In Fig. 5, both tunnels are under the building, or Churchyard, and are of circular section.

The first operation was to fasten 24-in. lattice girders on each side of the foundation walls. These girders are marked *L* 2, in Fig. 3, and are shown in detail in Fig. 6. At Fulton Street, the 24-in. girders were reduced to 12-in. so as to make room for the cross-girders marked *G* 5, in Fig. 3. These 12-in. lattice girders are marked *L* 1. The func-

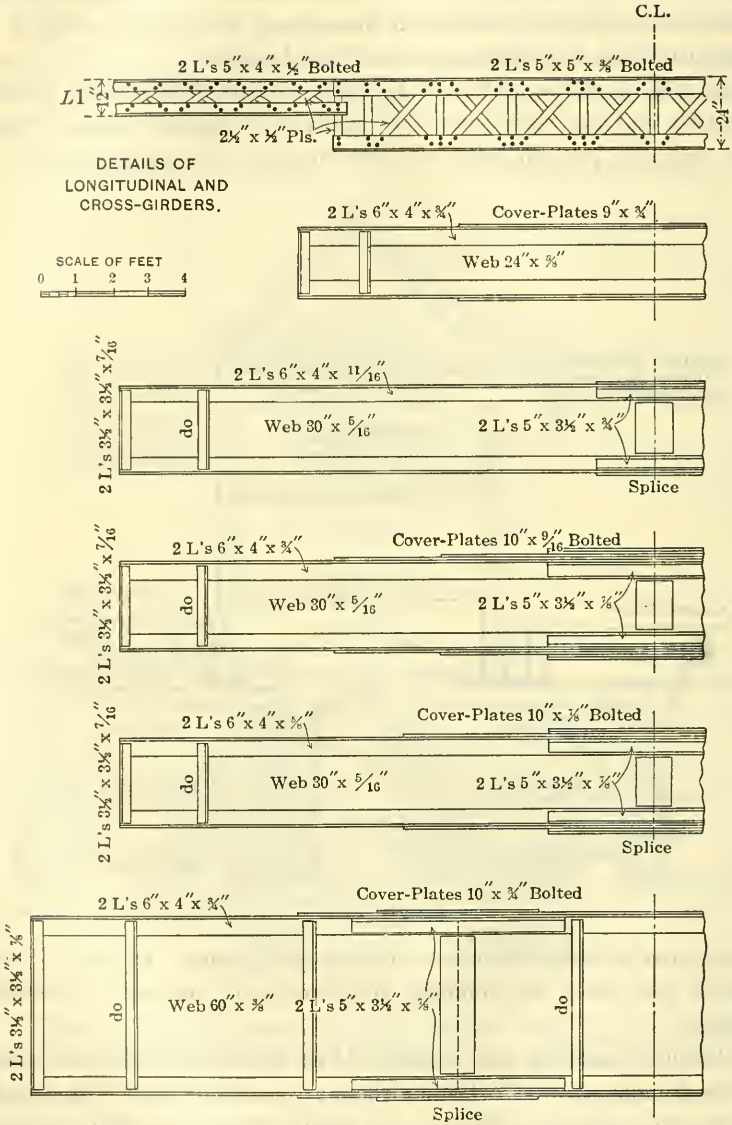

C.L.
2 L's 5"x 4"x ½"Bolted
2 L's 5"x 5"x ⅜"Bolted
L1
L2
2½"x ½"Pls.
DETAILS OF LONGITUDINAL AND CROSS-GIRDERS.
SCALE OF FEET
0 1 2 3 4
2 L's 6"x 4"x ¾"
Cover-Plates 9"x ¾"
Web 24"x ⅝"
L3
2 L's 6"x 4"x 11/16"
2 L's 3½"x 3½"x 7/16
do
Web 30"x 5/16"
2 L's 5"x 3½"x ¾"
G1
G5
Splice
2 L's 6"x 4"x ¾"
Cover-Plates 10"x 9/16 Bolted
Web 30"x 5/16"
2 L's 5"x 3½"x ⅞"
G2
2 L's 6"x 4"x ⅝"
Cover-Plates 10"x ⅞"Bolted
Web 30"x 5/16"
2 L's 5"x 3½"x ⅞"
G3
Splice
2 L's 6"x 4"x ¾"
Cover-Plates 10"x ¾"Bolted
2 L's 3½"x 3½"x ⅞"
Web 60"x ⅜"
2 L's 5"x 3½"x ⅞"
G4
Splice

FIG. 6.

tion of these longitudinals was to strengthen and tie the brickwork together, that is, to make it more monolithic in character. The brick walls were thus enabled to distribute the loads from above over longer lengths, and to span safely the openings which were to be dug subsequently for the concrete underpinning piers.

At one place on the Church Street side, 24-in. longitudinal plate girders, 20 ft. long, were used in place of the 24-in. lattice girders. These are marked *L* 3, in Fig. 3. This change in design was made so that the load of the side-wall could be carried over a space left between nests of cross-girders, which had to be placed diverging, so that their

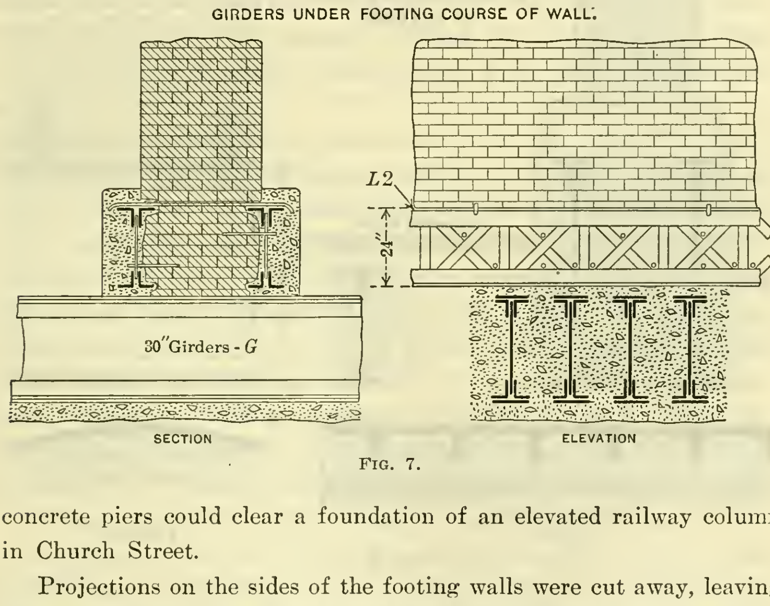


Fig. 7.

concrete piers could clear a foundation of an elevated railway column in Church Street.

Projections on the sides of the footing walls were cut away, leaving the vertical surfaces somewhat rough. This cutting was done by both hand-drills and by power channel drills. Grooves were cut for the angles of the top and bottom chords, in order that the girders could fit snug against the walls.

The girders were then doweled to the walls at frequent intervals. The dowels were square rods driven into the walls and bent over to catch the framing of the girders. Ties also were inserted in holes drilled through the wall at intervals. These bound the top chords of

the inside and outside girders together. The arrangement is illustrated in Figs. 7 and 8. After the girders were in place they were embedded in concrete, a strong bond being secured by the friction of the roughed surfaces of the sides of the walls aided by the dowels. To facilitate the placing of these girders, they were built up in place and bolted. Splices were staggered, both of the upper and lower chords and of parallel girders. Fig. 2 shows a 24-in. longitudinal lattice girder in process of erection. It is similar to those used under the Vestry Building.

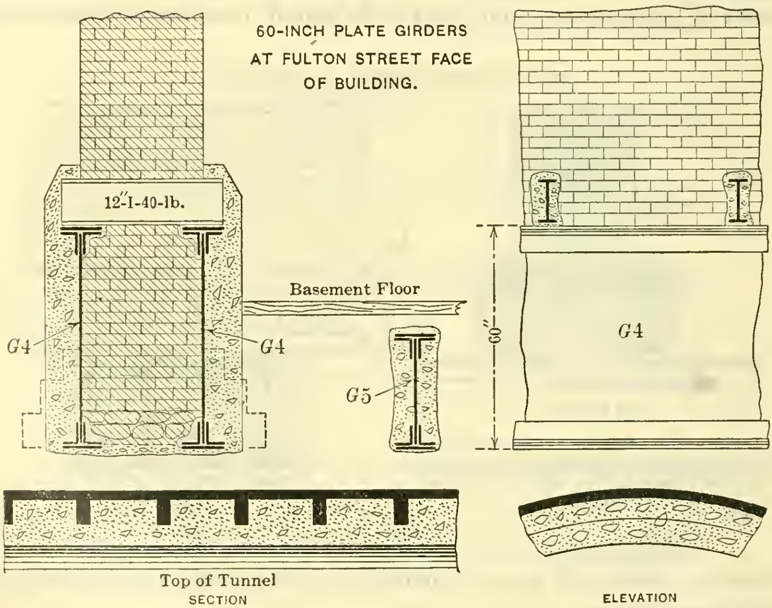


Fig. 8.

Across the Fulton Street face, two 60-in. plate girders were used in the same manner as the side lattice girders. These 60-in. girders are marked G 4, in Fig. 3, and were made in three parts for convenience in placing, the sections being bolted together when in position. They were tied together by 12-in. I-beams, 40 lb. per ft., as shown in Fig. 8, and were encased in concrete. The weight of the wall was transmitted to the girders by these needle I-beams, as it was not deemed wise to rely on the bond of the concrete casings.

After completing the work of fastening the longitudinal girders, G 4, L 1, L 2, and L 3, excavations for the underpinning piers were commenced. Excavations for adjacent piers were not made at the same time. When one pit was started, the next would be 30 or 40 ft. away, or as far as convenience would allow.

The pits were sunk by hand digging. As the excavations proceeded, the sides were box-sheathed with 2-in. planks laid horizontally. These planks were cut to fit, and when a set of four was in place the pieces were toe-nailed at the corners. When an excavation had advanced sufficiently, a 3 by 3-in. timber was put in each corner and spiked. Occasionally, these corner timbers were cross-braced with waling pieces which were wedged into place. No difficulty was experienced in this work. The average time required for three men to sink one of these pits varied from 3 to 6 days, including from 1 to 2 days in making the access.

Each pit was filled with concrete as soon as excavated. For piers directly under the walls, the spaces between the concrete tops and the footing course were packed with brick and cement, all tightly wedged, so that such pits could receive their share of the building load. For piers not under the walls, the plate girders, marked G 1, G 2, G 3, and G 5, in Figs. 3 and 6, were put into place and secured. The spaces between these girders and the footing course were then packed, and a portion of the load was transferred to the concrete piers, as before. These cross-girders were then encased in concrete, so as to protect the steel and make the nests of girders into solid floor-slabs. This feature is best understood by referring to Figs. 3 and 7.

As there were 115 of these concrete piers, each 5 ft. square, the average load on each was, for the present building (6 393 tons divided by 115 times 25) = 2.22 tons per sq. ft.; or, for the assumed future building, would be (10 300 tons divided by 115 times 25) = 3.58 tons per sq. ft.

In the Churchyard, some of the graves and vaults were in the way of the pit excavations. To avoid disturbing them, cross-tunnels were routed in from convenient sides, at sufficient depths to clear the graves, as shown in Fig. 5. When the correct locations were reached by the cross-tunnels, the pit excavations were carried down vertically in the usual manner.

It was the original intention to excavate the pits for the concrete piers to about ground-water level and then to drive concrete piles to a depth below sub-grade. As the subway pumping reduced the ground-water level, the plan was changed, the pits being carried down to about 1 ft. below sub-grade, and the piles omitted. However, at the Fulton Street end, short concrete piles were used under the pits, as seen in Fig. 4.

Elsewhere on this subway route some similar concrete piles were tested by the contractors, under the supervision of the writer. As these tests were interesting, the results are here given.

Two piles were tested under columns of the elevated railway in Trinity Place, between Rector and Thames Streets, during January, 1913, and three piles were tested under the retaining wall of Trinity Churchyard, just north of Rector Street, during February, 1913.

The piles were made by forcing into the sand a steel casing 14-in. in diameter, No. 12 gauge (about $\frac{1}{8}$ in. thick). The casing was made in sections about 24 in. in length, each section having an inside sleeve so as to permit one section to fit on top of the one just below, see Fig. 9. The steel casing was sunk by a pile-driver until its upper edge was level with the sand; then a new section was inserted, and the driving was continued until the proposed depth of pile was reached. The sand was removed by a small grab-bucket from the inside of the casing as the sections were sunk. When the entire casing was in place and the sand had been removed from the inside, the pile was formed by filling the casing with 1 : 2 : 4 concrete. For filling below ground-water, the concrete was put in paper bags and the bags were lowered into place and tamped. After about 2 ft. had been filled in this way the concrete was placed by a bottom self-dumping bucket.

The piles were tested, after the concrete had set, by a hydraulic jack, using the footing courses of the foundations as a base against which the jack was blocked. Owing to the short stroke of the jack, the pressure had to be relieved and the blocking readjusted as each pile sunk under the test loads. Whenever the pressure was relieved, there was a slight rebound of the pile. A graphic representation of Test IV is shown in Fig. 9, which illustrates this rebound.

Test I.—Steel casing, 9 in. outside diameter, driven inside a 14-in. casing which had buckled. The pile was 15 ft. long, and projected

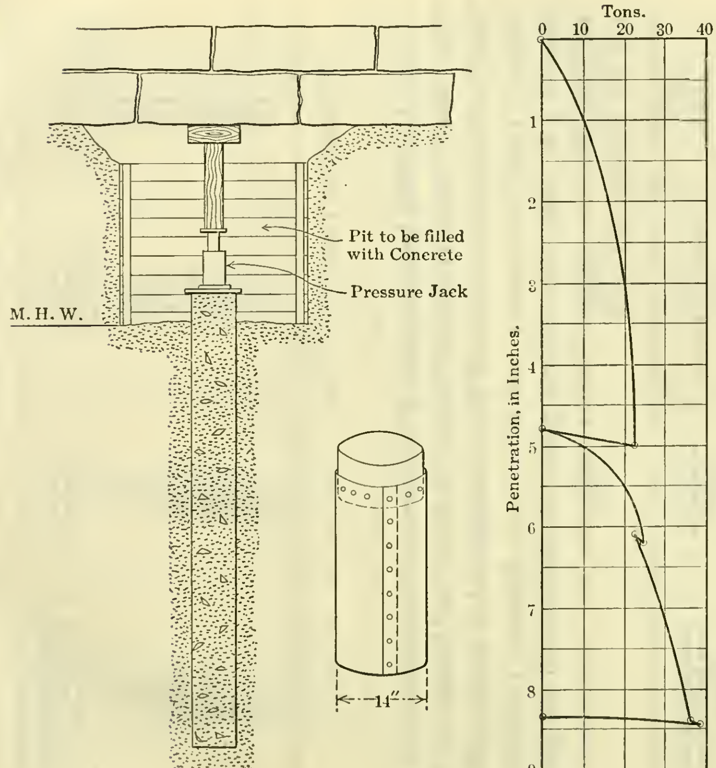


Fig. 9.

TEST OF
14 INCH CONCRETE PILE,
AND GRAPHIC RECORD OF TESTS.

Time.	Load, in Tons.	Penetration, in Inches	
		Each Test	Total
	0.0	0.0	0.0
	23.2	5.0	5.0
	0.0 +	0.250 ⊠	4.750
2:42	25.8	1.625	6.375
2:47	24.5	0.250 ⊠	6.125
2:48	32.0	1.375	7.500
2:53	30.2	0.0	7.500
2:54	36.5	0.875	8.375
3:04	38.3	0.062	8.437
3:05	0.0	0.125 ⊠	8.312

\+ Pressure relieved, to reset blocking.

⊠ Rebound when pressure was relieved.

about 2 ft. below the 14-in. casing. The 9-in. casing was filled with concrete. The soil was fine, wet sand.

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
3:59	0.0	0.0	0.0
4:00	0.63	0.0	0.0
4:06	18.80	0.276	0.276
4:16	21.40	0.012	0.288
4:18	31.40	0.228	0.516
4:28	31.40	0.156	0.672
4:33	31.40	0.024	0.696
4:37	37.70	0.864	1.560
4:42	37.70	0.324	1.884
4:45	0.0	0.336*	1.548

* Rebound when pressure was relieved.

Test II.—This test was made to measure the end resistance of a 9-in. outside diameter, pointed casing. A 14-in. steel casing, 12 ft. long, was first sunk, and about 2 ft. of sand allowed to remain at the bottom. Inside this casing a steel pile 9 in. in diameter, 14 ft. 6 in. long, of ½-in. steel, with cast-iron point, was driven until the point was below the outer casing. Neither casing was filled with concrete. The soil was fine, wet sand.

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
3:15	0.0	0.0	0.0
3:16	6.3	0.875	0.875
3:18	12.6	4.0	4.875
3:24	0.0*	0.125†	4.750
3:26	12.6	0.8125	5.5625
3:29	14.4	1.1875	6.75
3:31	18.8	2.125	8.875
3:34	0.0*	0.25†	8.625
3:38	23.2	7.625	14.25
3:44	0.0*	0.1875	14.0625
3:46	25.1	1.1875	15.25
3:51	25.1	1.0	16.25
3:52	0.0*	0.1875†	16.0625
3:57	31.4	1.8125	17.875
4:02	31.4	0.6875	18.5625
4:03	34.6	1.375	19.9375
4:06	0.0*	0.3125†	19.625
4:08	31.4	0.5625	20.1875
4:09	34.6	1.125	21.3125
4:10	34.6	0.75	22.0625
4:11	34.6	0.625	22.6875
4:12	0.0*	0.3125†	22.375

* Pressure relieved, to reset blocking under jack.
† Rebound, when pressure was relieved.

Test III.—Steel casing, 14 in. in diameter; length of pile, 18 ft.; concrete, 1 : 2 : 4 mixture, allowed to set for 10 days. The soil was fine, wet sand.

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
4:10	0.0	0.0	0.0
4:11	1.9*	0.0	0.0
4:18	32.0 } 28.9 } †	2.940	2.940
4:21	34.5 } 31.3 } †	2.052‡	4.992

* Pile started to move when a load of 23 tons was reached.
† Load slowly reducing by a leak in pump.
‡ Rebound was not recorded.

Test IV.—Steel casing, 14 in. in diameter; length of pile, 12 ft. A concrete plug, 48 hours old, 13½ in. in diameter and 18 in. long, was first dropped into the casing. Concrete was poured into the casing above the plug and allowed to set for 9 days. The soil was fine, wet sand.

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
....	0.0	0.0	0.0
....	23.2	5.0	5.0
....	0.0*	0.250†	4.750
2:42	25.8	1.625	6.375
2:47	24.5	0.250†	6.125
2:48	32.0	1.375	7.500
2:53	30.2	0.0	7.500
2:54	36.5	0.875	8.375
3:04	38.3	0.062	8.437
3:05	0.0	0.125†	8.312

* Pressure relieved, to reset blocking under jack.
† Rebound, when pressure was relieved.

Test V.—Steel casing, 14 in. in diameter; length of pile, 16 ft. 6 in.; concrete, 1 : 2½ : 4½ mixture, allowed to set 17 days.

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
9:40	0.0	0.0	0.0
9:42	12.6	0.1250	0.1250
9:42:30	18.8	0.3750	0.5000
9:43:30	25.1	1.1250	1.6250
9:53:30	25.1	0.4375	2.0625

Test V.—(Continued.)

Time.	Test load, in tons.	Penetration, in inches.	Total movement from start of test, in inches.
9:54:30	31.4	0.9375	3.0000
10:04:30	31.4	0.2500	3.2500
10:06:00	35.8	1.1250	4.3750
10:08:00	0.0*	0.3750†	4.0000
10:17:00	6.3	0.0	4.0000
10:17:20	12.6	0.5000	4.5000
10:17:30	18.8	0.0	4.5000
10:17:40	25.1	0.0	4.5000
10:18:00	31.4	0.0625	4.5625
10:19:00	36.4	0.8135	5.3750
10:19:20	37.7	0.3750	5.7500
10:24:20	37.7	0.3750	6.1250
10:29:20	37.7	0.1250	6.2500
10:34:20	37.7	0.0	6.2500
10:49:20	37.7	0.0	6.2500
10:50:20	0.0	0.3125†	5.9375

* Pressure relieved, to reset blocking under jack.
† Rebound, when pressure was relieved.

Some conclusions, deduced from a study of the test loads and penetrations, are:

(1) The initial loads, which the piles supported before sinking, were variable.

(2) The sinking increases more rapidly than the load.

(3) When the pressure is relieved, the pile rebounds.

(4) When the same load is again put on the pile, the penetration is greater than the original penetration, that is, the pile sinks more than its rebound.

(5) The supporting power of one of these concrete piles depends chiefly on the area of its base. The side friction in sand probably does not exceed from 5 to 8% of the load.

(6) To secure the maximum supporting power without additional settlement, a concrete pile should receive its permanent load while under pressure, that is, the permanent underpinning load should be transferred to it without relieving the test load.

(7) This latter condition can be accomplished by placing struts between the footing to be underpinned and the pile top before the pressure of the jack is relieved.

After the underpinning work had been completed, and the load of the Vestry Building had been transferred to its new foundations, excavation beneath the basement was commenced, and the tunnels were

allowed to advance toward the building. At the same time, excavation under Church Street, which had been decked with wood, also was being made.

The tunneling commenced from a shaft in Vesey Street, and the east tunnel was kept somewhat in advance of its westerly mate. Both tunnels were worked forward from Vesey Street across the Churchyard toward Fulton Street. They are 20 ft. in outside diameter, and are lined with cast-iron plates covered with concrete inside.

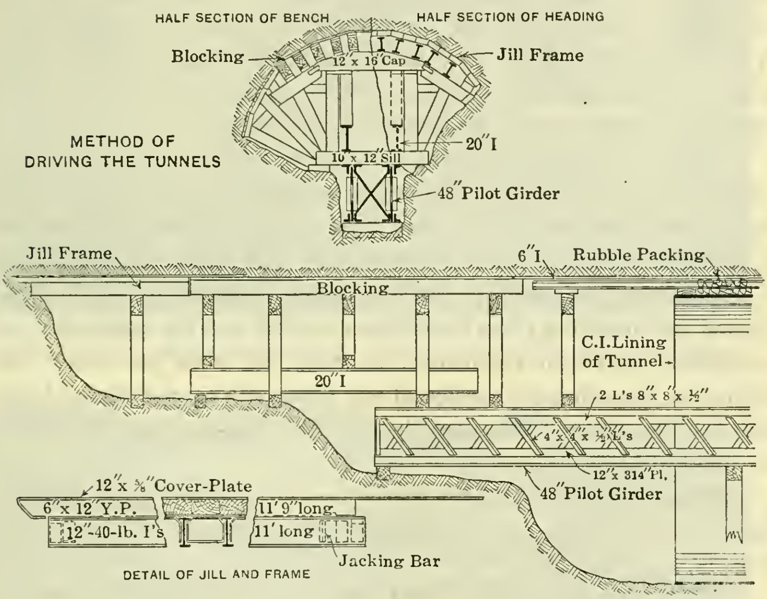


FIG. 10.

As the soil was sand, varying from fine to medium coarse, the method of tunneling adopted by the contractors is shown in Fig. 10. Jills, arranged side by side in the curve of the roof, and supported by cap timbering, were driven forward by jacks. As the jills were pushed ahead, the space behind them was sheeted and filled with blocking resting on the caps. The sides of the tunnel were sheeted with 2-in. planks, held in place by braces and struts. A steel pilot girder formed the base from which the various braces and capping were supported. This pilot girder also formed the truss for supporting the centering machine which raised and put the cast-iron lining sections in place.

The excavation was carried forward by an advance drift close under the roof, and benches formed by deeper excavations to sub-grade were kept back at safe distances, depending on circumstances. Timbering was placed as the section was enlarged, and the cast-iron lining plates of the tunnel were erected as soon as the full section was cut. Fig. 11 shows one of the headings as it advanced under the Churchyard.

The jills were made of timber, sheathed with steel plates bent over the forward nose to form a cutting edge. These jills rested on, and were bolted to, steel frames, built up as seen in Fig. 10, and were all supported on timber capping braced radially from the tunnel center. They were pushed ahead by hydraulic jacks, the center one being kept slightly in advance of the others. The sand was removed in cars to the Vesey Street shaft and hoisted to the street.

The tunneling was accomplished without serious accident, although the method required great care and attention to prevent slips. There was a noticeable loss of sand, that could not be avoided, and there was a slide of sand at one place which caused a marked settlement of the Churchyard. The engineers of the Public Service Commission approved the tunneling plans before work started, and the contractors are entitled to credit for the manner in which the work was done. The tunneling beneath the Churchyard was accurately carried forward, and the headings entered the spaces between the concrete foundation piers as planned.

When the drift reached the partial excavation beneath the building, the advancing jills, as they emerged from the sand, are shown in Fig. 12.

Fig. 13 shows the excavation beneath the building. The concrete foundation piers are seen on both right and left, and the concreted cross-girders are shown overhead. The cast-iron lining of the tunnel can be seen in the background. As the lining plates were erected, the spaces around them were back-filled.

Fig. 14 is another view of the excavation beneath the building. The basement windows can be seen through an opening between the concreted cross-girders.

Fig. 15 shows the east tunnel at Fulton Street, with the concreted cross-girders, *G* 5, overhead. At the top of the picture in the foreground is seen the footing course of the Fulton Street wall of the building.

FIG. 11.—VIEW IN ADVANCE HEADING OF TUNNEL UNDER ST. PAUL'S CHURCHYARD.

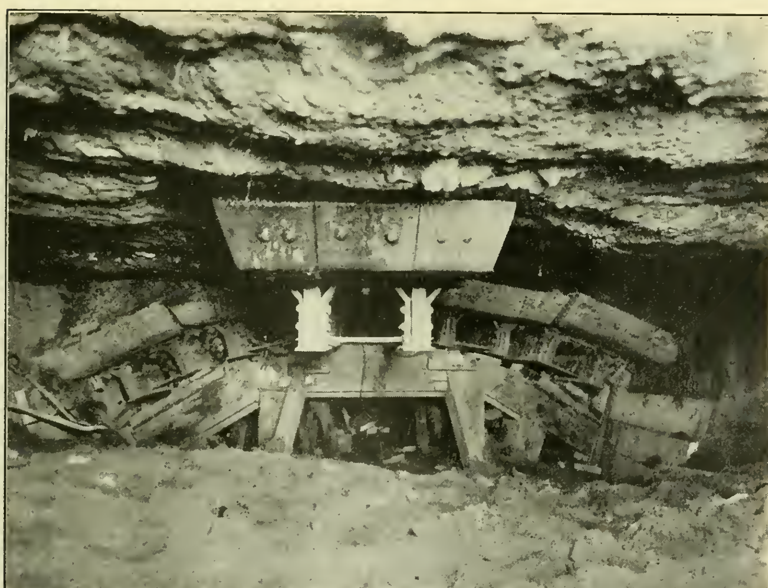


FIG. 12.—TUNNEL JILLS BREAKING INTO SPACE UNDER TRINITY VESTRY BUILDING.

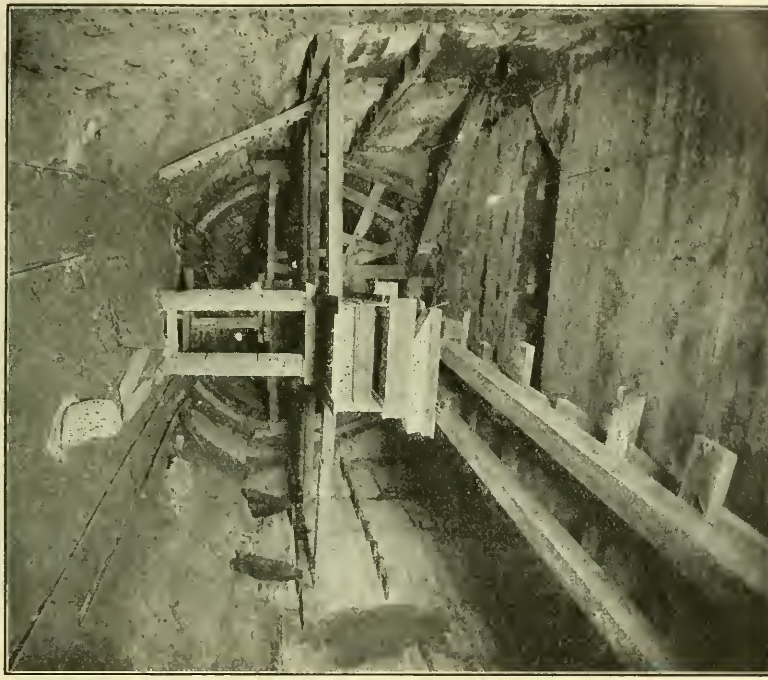


Fig. 13.—View Under Trinity Vestry Building with the Concrete Piers on Both Right and Left.

Fig. 14.—View Beneath Building, Showing Basement Windows Between Concreted Cross-Girders.

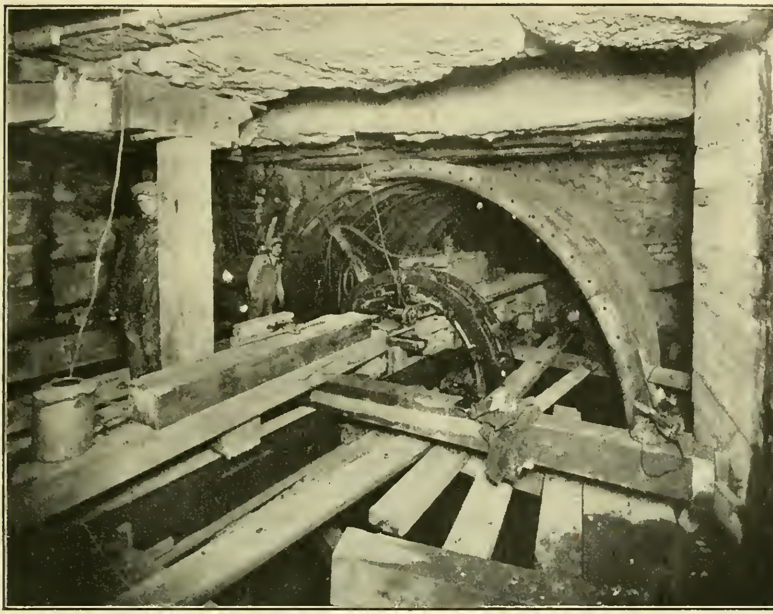


FIG. 15.—EAST TUNNEL AT FULTON STREET. FOOTING COURSE OF BUILDING IS SHOWN OVERHEAD.

FIG. 16.—VIEW SHOWING CONCRETE KEY ON INSIDE OF COMPLETED CAST-IRON LINING.

Fig. 16 is a view inside the completed cast-iron lining of one of the tunnels. It shows the concrete key of the inside lining which was jacked into place in advance of the general lining.

The work of underpinning and of transferring the load to the new piers caused a settlement of the building, as shown by the surveys, as follows:

At N.E. Corner, on Vesey Street	$1\frac{11}{16}$ in.
" N.W. " " " "	$1\frac{5}{16}$ "
" center of Churchyard side	$1\frac{13}{16}$ "
" " " Church Street side	$2\frac{5}{16}$ "
" S.E. Corner, on Fulton Street	$2\frac{13}{16}$ "
" S.W. " " " "	$2\frac{3}{8}$ "

A few cracks of minor importance developed, and the plaster spalled in some places.

As shown by the survey figures, the settlement was very uniform. This even settlement, and the slight damage to the building, resulted from digging the pits without regularity, that is, by not excavating them from one end of the building toward the other.

The contract price for this section of the subway, extending from a point on Broadway, just north of Barclay Street, to Church Street, a distance of 1 030 ft., was \$982 740.

The work of underpinning was commenced in June, 1913. The longitudinal girders along the wall footings and the cross-girders were all placed by February, 1914. Both tunnels were completed beneath the building by June, 1914. The back-filling under the building was completed and the basement floor and rooms restored by October, 1914, or 17 months after the active work of underpinning was started. The final restoration of the property was delayed by the work under Church Street, requiring the adjustment of street steam-supply pipes, telephone ducts, sewers, etc., until April, 1916.

The contractors were Frederick L. Cranford, Inc., and the work was done under the personal direction of Mr. F. L. Cranford and J. C. Meem, M. Am. Soc. C. E.; the Superintendent on the work was Mr. H. L. Robinson, and the Assistant Engineers were Messrs. H. P. Moran, in charge of the office, and W. McI. Wolfe, Assistant Engineer on field work. For the Public Service Commission, Alfred Craven,

M. Am. Soc. C. E., was Chief Engineer; Robert Ridgway, M. Am. Soc. C. E., Engineer of Subway Construction; and Mr. Jesse O. Shipman, Division Engineer. The writer was Consulting Engineer for the Corporation of Trinity Church, and was assisted in supervising the work by D. C. Johnson, Assoc. M. Am. Soc. C. E., and Mr. W. E. Moore. The photographs were taken by Mr. Edwin Levick.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

INDUCED CURRENTS OF FLUIDS

Discussion.*

By F. zur Nedden, Esq.†

F. zur Nedden,‡ Esq. (by letter).§—The writer is highly gratified that his paper has brought forth such a valuable contribution to the knowledge of the flow of fluids in centrifugal pumps as that contained in Mr. de Laval's discussion. Mr. zur Nedden.

There are only a very few points where an explanatory remark would seem necessary. For instance, Mr. de Laval has not interpreted the paper correctly if he understands the writer to maintain that secondary currents exist at all flows.|| By reference to pages 1384-86¶ it will be found that the statement is emphasized that vessels offering a minimum of resistance to flow below the critical limit can offer a maximum of resistance above the critical limit, due to induced currents forming in the latter case and not in the former. As this is an engineering paper, it deals throughout with speeds above the critical limit, only such speeds being generally of interest to the engineer; those below that limit fall mostly within the domain of the physicist.

The two critical speeds which Mr. de Laval mentions on page 2475** are of no importance to the engineer. From the use he makes of the term "critical velocity" later (on page 2476**, Paragraph 3), it would seem that he means by it something quite different from the well-defined scientific term.

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* Discussion of the paper by F. zur Nedden, Esq., continued from December, 1915, *Proceedings*.

† Author's closure.

‡ New York City.

§ Received by the Secretary on May 16th, 1916.

|| *Proceedings*, Am. Soc. C. E., for November, 1915, p. 2473, paragraph 4.

¶ *Proceedings*, Am. Soc. C. E., for August, 1915.

** *Proceedings*, Am. Soc. C. E., for November, 1915.

Mr. zur Nedden.

It certainly is a source of great satisfaction that the results obtained from diffusors such as Fig. 28 confirm the writer's theories in such a remarkable way.

Fig. 29 is an example of the practical application of the writer's recommendation to steady the flow at the entrance to impellers by decreasing the area. The same is true of the auxiliary inlet vanes such as Fig. 35.

It is gratifying to have as complete a vindication of the writer's thesis as the following sentence on page 2483* by Mr. de Laval, one of the highest authorities among pump manufacturers in the United States: "The common suction elbow will not do."

The alleged bad experiences of Mr. de Laval with his auxiliary profiles is not considered as conclusive evidence against the expedient recommended by the writer. The shape of the entrance chambers might have had much to do with the failure of his experiments in 1910. How great this influence is, can easily be ascertained from his excellent comparison, illustrated by Fig. 38, which indeed "speaks volumes".

The writer is confirmed in his conviction of the supreme value of the auxiliary stream line profile by the great success which this expedient has secured in the latest designs of high-speed turbines by Messrs. Voith, of Heidenheim.†

Mr. Trautwine has misunderstood that part of the paper which refers to the resistance due to a bend. The writer's opinion is based on those experiments by Messrs. Williams, Hubbell and Fenkell which Mr. Trautwine quotes as proof to the contrary.

The writer wishes to express his thanks to the participants in the discussion, and especially to Mr. de Laval, who has furnished information of exactly the kind which it was hoped to bring out.

* *Proceedings*, Am. Soc. C. E., for November, 1915.

† Described by Oesterlen in Nos. 40 and 42 of *Zeitschrift* des Vereins Deutscher Ingenieure, 1915.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

CHEMI-HYDROMETRY AND ITS APPLICATION TO THE PRECISE TESTING OF HYDRO-ELECTRIC GENERATORS

Discussion.*

By Benjamin F. Groat, M. Am. Soc. C. E.†

Benjamin F. Groat,‡ M. Am. Soc. C. E. (by letter).§—Mr. Kershaw's suggestions as to the use of the term "halo-hydrometry" are worthy of consideration; but the term is narrower than chemi-hydrometry, and thus fails to include chemicals which are not salts—acids, for example. Chemi-hydrometry includes color, conductivity, or any other property which can be changed by the introduction of a chemical. Mr. Groat.

The moving screen has been used in Europe to some extent, and has been proved to be more accurate than any other method of measuring large volumes of flowing water, with the exception of chemi-hydrometry, which may be made as accurate as desired, with sufficient care and expense. A full explanation of the method may be found in a paper entitled "The Diaphragm Method for the Measurement of Water in Open Channels of Uniform Cross-Section",|| by Carl Robert Weidner, Assoc. M. Am. Soc. C. E.

The method requires a diaphragm which fits the cross-section of a prismatic conduit, or flume, as closely as practicable. This screen traverses the length of the conduit on a carriage which rolls on wheels guided by a track. The volume described by the screen in any observed period of time is theoretically equal to the volume of water

* Discussion of the paper by Benjamin F. Groat, M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† Author's closure.

‡ Pittsburgh, Pa.

§ Received by the Secretary, June 3d, 1916.

|| *Bulletin* of the University of Wisconsin, No. 672, 1914.

Mr. Groat. flowing in the conduit during the same interval, supposing the screen to move with the average velocity of the water.

Concerning the action of the salt on the feed-water, the salt, being in very dilute solution, caused no "frothing" of the water when passing through the turbines, and there was no short-circuiting of the meters due to its presence in the water, although attention was called to its action on the water rheostat when it was used in Test No. 105. (See Section 109, concerning the first series of tests of Unit No. 11.)

The writer has used color in a series of tests with very satisfactory results. Colors may be matched accurately with a colorimeter, but there is no colorimeter specially adapted to the requirements of chemi-hydrometry, the need of which is suggested at the close of Section 39. The principal objection to color is its cost.

The Ott meter is made by A. Ott, Kempten, Bavaria. The Haskell meter is made by E. E. Haskell, M. Am. Soc. C. E., Cornell University, Ithaca, N. Y. The deep-sea Haskell type gives the velocity and direction of flow at any depth.

Mr. Fuller describes very interesting tests to determine the detention period for liquids flowing through tanks, and to determine capillary volumes by means of salt solutions injected into the influent and measured in samples of the effluent. It is very apparent that diffusion may have a considerable effect on the results thus determined where the velocity of diffusion is large relative to the velocity of the water, or other liquid, into which the salt is injected.

In the case of turbine tests, however, the velocity of the water is relatively high, and the mixture is so nearly perfect that the effects of diffusion are small; in fact, diffusion assists the rate of mixing, and produces a more uniform mixture than could otherwise be obtained. When the mixture is perfect, there is no diffusion.

The writer does not share with Mr. Peaslee the fear that engineers will imagine that they must duplicate all the detail of the work which was undertaken in order to develop a theory and method for chemical testing. It is very easy to see, for example, that the chemical method may be applied with great simplicity to the test of a centrifugal pump, as described in Section 51. It will be observed, of course, that no evaporations are necessary in this and similar cases, and that the necessary chemical equipment consists of a comparatively small salt-solution tank connected to the suction of the pump, with means for measuring the weight or volume of the solution consumed, and a very simple outfit for taking and treating the samples from the discharge.

In the case of larger operations, the tests need not be any more complicated, except that where great accuracy is required with large volumes of water to be measured, it will be found advantageous, in the majority of cases, to resort to evaporation for the purpose of concentrating the samples. About the only real difference between the

test of a turbine and the test of a pump lies in the magnitude of the operation, which varies to a less relative extent than the quantity of water measured. Nor is it expected that the reader will necessarily adopt the detail of any of the methods treated in this paper. Engineers are capable of planning their own tests. What they want is reliable theory and reliable information on which to base their calculations, estimates, and specifications, without the necessity of experimentation. It was this want that led to unusual efforts in the tests which form the subject of the paper, and the writer will indeed feel satisfied if it is considered that he has, in some measure, supplied the deficiency. Mr. Groat.

Mr. Peaslee's testing automobile is very interesting. There are, no doubt, many opportunities for the use of automobiles in transporting testing equipment from place to place, and it would seem that there is no reason why the titrations could not be performed on the spot by the men who execute the remainder of the test of any particular pump. With very little practice any engineer can make a titration to 0.1 or 0.2 of 1% by following, in a general manner, the directions in Sections 88 and 89. It should be remembered that the proper rate of draft for titration from an ordinary 75 or 100-c.c. burette is 8 or 10 c.c. per min.

Mr. Peaslee's description of his electrical equipment is very acceptable, as there are few papers, especially in English, on conductivity as applied to chemi-hydrometry. It might be remarked that with the application of the method of special dilutions, or balanced samples, Section 40, it will not be necessary to calibrate the instruments, as the procedure there described eliminates all the instrumental errors. In order to eliminate by special dilutions the effects of temperature, care must be taken to have each pair of tail-water and special-dilution samples at the same temperature. This follows as a corollary from the principle of balanced samples enunciated in the second paragraph of Section 12. One-tenth of a degree will affect the conductivity appreciably. With the exercise of care and judgment, the other errors, also, will be eliminated by a rigid application of the principle.

Mr. Waters asks for additional figures in connection with the readings, apparently referring to the readings for each of the eighteen tail-race samples taken in each test. The writer has published these in full detail on pages 2334 to 2356,* inclusive; and, in Section 50, one of the tests has been examined with respect to the distribution of salt among these eighteen samples.

The chemical data of each test have been given in full so that any one can make such study and analysis of them as he may desire, and the results of an investigation of this kind would be welcome. It is quite possible that there may be an error of computation in some of

* *Proceedings*, Am. Soc. C. E., for November, 1915.

Mr. Groat. the discordant tests, which could be discovered in this manner. The writer would appreciate being informed of any such discovery.

Mr. Waters is correct in his theory that it should be relatively more difficult to obtain a perfect mixture with relatively high turbine, or pump, efficiency. Practically, the power required in mixing must be very small. Imagine, for example, a barrel of 200 liters of water with, say, 20 "stream lines" or "pencils" of salt solution uniformly distributed in vertical positions throughout the volume. Let a man mix this with a single vigorous double stroke of a large churn dasher, which is then quickly removed from the barrel. One can scarcely doubt that in a few seconds after removing the dasher the mixture will be near to perfection. If not in a few seconds, then certainly within a minute, about the time required for the mixture to pass through the turbine from the sprinkling pipes to the sampling pipes.

The energy exerted by the man can probably be represented by an average of 10 lb. acting 2 ft. downward and then 2 ft. upward, say, 40 ft-lb., or 40 ft-lb. is sufficient energy to cause 200 liters of water and salt to mix while it is flowing from the sprinkling pipes to the sampling pipes. To mix 50 000 liters, the turbine discharge per second, would require 250 times the energy above calculated, or 10 000 ft-lb. If this amount of energy is supplied each second, the entire discharge of the turbine will be thoroughly mixed before it reaches the sampling pumps, and it is easy to see that the power required is about $10\,000 \div 550 = 18.2$, or less than 20 h. p., to mix the discharge of a 6 000-h. p. turbine. In all probability, the eddies generated by the flow of water through the trash racks and against the sprinkler pipes in the head-race are sufficient to cause the necessary mixing of the salt with the feed-water, and the mixing will be aided by any diffusion which may occur.

Mr. Horton suggests the term "aquametric" as one descriptive of matters relating to the measurement of water in general. This term, like chemi-hydrometry, is hybrid, and does not appear to furnish a very euphoneous noun. Aquametry is constructed of Latin and Greek roots, the pure Greek synonym being, simply, hydrometry. It does not appear that there should be any serious objection to the broader use of the term hydrometry, even though usage has given it a more restricted meaning in relation to density and specific gravity.

It was not the writer's intention to present primarily a paper on the current meter, but the methods used in correcting the indications of these instruments, and especially the composite ratings, were thought to be of sufficient interest to be presented in full.

In another series of tests it would be advisable to have readings by the two meters compared at each meter point. This would render the work of reduction much simpler, and be more satisfactory when it is desired to compute the discharge in each individual test. How-

ever, it will be observed, when treating all five of the tests in any series as though they were a single test, that the four methods of correcting the discharge give results which agree very closely, as may be seen in Table 85, where the difference between the maximum and minimum aggregates for Tests *G, H, I, K,* and *L,* as determined by the four methods, is only 8 in 1 340 or 0.6 per cent. That the agreement is not a mere chance may be demonstrated by comparing, in similar manner, the aggregates of velocity for Tests *N, O, P, Q, R,* as determined by the four methods, Table 93 giving the results for comparison. Mr. Groat.

TABLE 93.—Aggregate Velocity for Tests *N, O, P, Q, R,* by the Four Methods.

(Velocities, in feet per second.)

Factors based on tests.	Meters compared by:	Aggregate velocity.
G, H, I, K, L	Positions	1 471.5
G, H, I, K, L	Horizontals	1 469.0
N, O, P, Q, R	Positions	1 475.0
N, O, P, Q, R	Horizontals	1 471.4

In all probability, the individual tests, when computed by the four methods, would have compared about as well as those shown in Table 93, had it been possible to compare the records of meters at a given point in the same test. It will be observed that there are small systematic errors among the four methods. In this respect Table 85 seems to be quite consistent with Table 93.

The writer attributes the principal part of the deviations of current-meter ratings to the difference which exists in the condition of the water during the rating and at the time of the discharge measurement, and considers these deviations to be due only slightly to the fact that the meter is towed forward during the rating and held at a point during the discharge observations. In other words, he does not believe that there is any material difference in the hydraulic resistance of a liquid on a body, whether that body moves through the liquid or the liquid moves about the body, supposing the actual dynamic condition of the water, relative to the body, to be the same in the two cases.

Mr. Wiggin is very properly cautious as to the degree of accuracy of turbine tests, especially as to the possibility of apparent precision being in reality more or less fictitious or imaginary. When a whole series of tests is highly self-consistent, it may be safely concluded that the observations were made with a correspondingly high degree of precision as regards accidental errors. The theory of errors usually presented in treatises on probability, however, says nothing at all about systematic errors, which, indeed, are the errors most to be feared, as

Mr. Groat. they are generally masked or otherwise hidden, so as to be easily overlooked.

As to the proper degree of accuracy to be required in turbine tests and the constancy of turbine efficiency, Mr. Wiggin and the writer seem to have somewhat divergent views. From numerous power capacity tests and a number of complete tests where the discharge was also measured by the writer at different times, turbine efficiencies have been found to remain remarkably constant when the machines have been kept in uniform condition and not allowed to become damaged. There seems to be no reason to believe that there are any material variations of this sort in actual practice where the condition of the machinery is well maintained. Good evidence to this effect may be found in the three series of tests on Unit No. 13. These tests extended over the period from July 22d to September 2d, inclusive, and no indication of variation in efficiency is observable. Turbines which were tested in 1911 still have the same capacity curves which were determined at that time. The writer is of the opinion that turbine testing, especially as to the measurement of the water, has been altogether too crude, and that the present requirements demand an increase in the degree of precision for the tests.

It would appear that a unit of power gained by an increase in efficiency is more valuable than a unit of power requiring an additional amount of construction. For it brings the same price on the market and requires no investment other than the cost of securing the increase in efficiency, which perhaps involves nothing more than the engineer's judgment in selecting the better of two designs, and thus is obtained without any increase of expense in operating the hydraulic part of the plant. Of course, there may be required a slight increase of cost and operating expenses for the electric part of the plant in the case of hydro-electric developments. Therefore, if a hydro-electric development costing $100 per h. p. is a paying proposition, and additional power can be had by an increase in efficiency, there is no reason why this additional power would not be well worth $100 per h. p. also, supposing that the market will absorb it without being affected. Perhaps it would be satisfactory to divide the gain due to increased efficiency between the purchaser and the turbine maker by letting the bonus be one-half of the development cost, due to the construction of the hydraulic part of the plant, including dams, canals, gates, flowage rights, etc. Great caution should be exercised in specifying turbine performance where power is to be developed by means of high efficiency. It would be very easy, indeed, to test turbines and pay a bonus at the rate of $100 per h. p., or one-half of this, only to find that operating conditions would seldom, or never, admit of working the machines under the conditions which secure this power. In all probability, specifications involving these large rates of bonus

should not specify maximum turbine efficiency, but rather the minimum efficiency for a considerable range of probable operating conditions, such ranges of condition, for example, as might be specified by mentioning a definite area on a diagram similar to Plate LXVI. Mr. Groat.

There is no reason why chemical tests should be more expensive than tests of other kinds. In all probability, they can be made less expensive, especially for a given degree of accuracy. Turbine tests are more or less costly, because they are very complicated, no matter what method is adopted. It requires a considerable number of observers to obtain the data, particularly where the power is measured electrically. Moreover, a large number of tests are required where any attempt is made to cover the range of operating conditions. These remarks relate, of course, to very large power units. A small machine, such as a Pelton wheel or a centrifugal pump, can be tested chemically, with high precision, for a few dollars. The same is true of a water main, though large sizes may present greater difficulty.

The cost of turbine tests will depend on circumstances and on the methods and details adopted by the testing engineer. With the essential methods of testing well in mind, an engineer should be able to devise his tests and make accurate estimates of the cost. He need not be surprised, however, if he should find his estimate to be in the neighborhood of \$5 000 for fifty or a hundred tests on a 10 000-h. p. turbine on a head of 50 ft., though circumstances might reduce this to \$3 000, or even less. These costs are supposed to include the cost of electrical instruments and the engineering service necessary to conduct the tests and compute the results. The reason these figures seem high is because the tests are turbine tests, and not because they are chemical tests. Circumstances may run the cost higher still.

The writer remembers Mr. Richmond with pleasure. It is true that the meter sections which Mr. Richmond saw were unusually poor, and it is this fact that makes the meter work more valuable, for it shows what corrections are necessary under such conditions. The writer thinks, however, that the conditions for chemical work were favorable, and that there should not be too great a distance between the dosing and sampling stations. Otherwise, the eddies and dead water will require such a long time to fill with chemical that an accurate test will be difficult or impracticable. In the case of large cross-sections, it is advisable to introduce the chemical from the sprinkling pipes on the down-stream side of the trash racks properly stopped sufficiently to raise a head of 8 or 10 in., thereby securing an almost uniform mixture at the outset.

The close agreement between some of the current-meter and chemical tests published in the paper is probably more or less accidental, but the writer is led to the belief that current meters can be used successfully in the manner described, so as to secure a degree of

Mr. Groat. precision within 1%, if this was not actually secured in the present case.

There are two conclusions with which Mr. Richmond disagrees. The writer believes in rigid supports, properly designed, cupped, screw runners, and no tails or rudders, and he states on page 2104*:

"The uncertainty attending the measurement of large volumes of flowing water by methods heretofore used, under the most favorable circumstances * * * , is * * * , [for the current meter] 2 to 8%, and even higher."

In advocating rigid supports and no tails, the writer had in mind the measurement of turbulently flowing water in sections which, perhaps, might ordinarily be thought to be wholly unsuitable for a discharge measurement. That the discharge can be accurately thus measured in such sections by means of rigid supports and proper methods of correcting the meters seems to be accomplished in the tests, and this where the ordinary method would surely fail by a relatively large amount. Even under favorable conditions, the writer adheres to rigid supports and no tails, and advocates a new type of runner designed so that its record will always give the true integrated component of velocity perpendicular to the cross-section. There is plenty of evidence that the latter design may be effected without much experimentation.

The writer's statement concerning the accuracy of current-meter work under favorable circumstances refers to the accuracy of discharges, determined by the meters, and not to tests of the accuracy of the instruments. This is probably the cause of the misunderstanding. Ample authority for the statement can be found in the reports of the Lake Survey engineers. As an example, the interested reader may refer to the Annual Report of the Chief of Engineers on the Survey of the Northern and Northwestern Lakes for 1902, Appendix EEE. The report of F. C. Shenehon, M. Am. Soc. C. E., begins on page 2779, and shows a discharge curve of the St. Lawrence River with limits for errors immediately preceding page 2793. The limit of error is 2% either way, from the discharge curve. These are accidental errors. There is nothing to show that the systematic error may not be larger. Opposite page 2826 will be found a plotting of a discharge curve by L. C. Sabin, M. Am. Soc. C. E., showing errors in the plotted points of several per cent. The report of W. Edward Wilson, M. Am. Soc. C. E., beginning on page 2872, contains a discharge curve of St. Marys Rapids similar to the others. There are many other curves in these reports, and a careful study of them will soon convince any one that errors of 2% are common in current-meter work of the best quality.

* *Proceedings*, Am. Soc. C. E., for November, 1915.

In the case of tests of the meters with a quantity of blueing injected into the water and timed over the distance between the two meters, it is gratifying to note the close agreement between the actual velocity and that indicated by the meters. The fact that the ball of blueing remained intact, however, shows that there was little turbulence in the water and, therefore, little cause for errors. Mr. Groat.

Shrinkage.—As the question of shrinkage will be of importance in many investigations, it will be of advantage to systematize the methods for computing the values of the shrinkage coefficient, and the following remarks will be of interest.

By Equation (63), Section 23,

$$k = \frac{C_2 - C_1 - (D_2 - D_1)}{C_2 D_1 - C_1 D_2} = \frac{d\,(c_2 - c_1) - c\,(d_2 - d_1)}{c_2 d_1 - c_1 d_2} \quad (204)$$

Therefore,

$$k = \frac{1 - \dfrac{c}{d}\,\dfrac{d_2 - d_1}{c_2 - c_1}}{\dfrac{d_1}{d} - \dfrac{c_1}{d}\,\dfrac{d_2 - d_1}{c_2 - c_1}} = \frac{d}{d_1}\left(\frac{1 - p\,\dfrac{\Delta d}{\Delta c}}{1 - p_1\,\dfrac{\Delta d}{\Delta c}}\right) \dots\dots\dots (205)$$

where $p = \dfrac{c}{d}$, $p_1 = \dfrac{c_1}{d_1}$, etc., and $\Delta d \div \Delta c$ is the mean rate of change of density per unit change of concentration.

If the reciprocal of this ratio, $\Delta c \div \Delta d$, which is the mean rate of change of concentration per unit change of density, be indicated by α, then it will be easy to show that

$$\left.\begin{aligned} k &= \frac{d}{d_1}\left(\frac{\alpha - p}{\alpha - p_1}\right) \equiv \frac{d}{d_2}\left(\frac{\alpha - p}{\alpha - p_2}\right) \\ &= \frac{d}{d_1}\left(1 - \frac{p - p_1}{\alpha - p_1}\right) \equiv \frac{d}{d_2}\left(1 - \frac{p - p_2}{\alpha - p_2}\right) \end{aligned}\right\} \quad (206)$$

It will be noticed that α is the mean slope, for a given temperature, of a curve on Plate XLVIII, Section 4, with reference to the vertical axis of co-ordinates, for the two points which indicate, respectively, the condition of the solution which is to be mixed with the salt solution and the condition of the resulting mixture, the symbols p and d, of course, relating to properties of the strong salt solution itself. The second form of the equations is for use with the slide-rule.

The formula is perfectly general, and may be used to find the value of $\boldsymbol{k''}$ by letting the subscripts, 1 and 2, relate, respectively, to the condition of special dilution and the condition of tail-water. Or, the subscript 1 may be changed to accord with the adopted notation, for this case, as follows:

$$\boldsymbol{k''} = \frac{d}{d'_2}\left(\frac{\alpha - p}{\alpha - p'_2}\right) = \frac{d}{d_2}\left(\frac{\alpha - p}{\alpha - p_2}\right) \dots\dots\dots\dots (207)$$

Mr. Groat. Here α relates to the slope of the tangent to one of the curves of Plate XLVIII, with reference to the vertical axis of co-ordinates, at a particular point, as there is supposed to be only a very slight difference between the corresponding properties of the special dilution and tail-water at the given temperature, thus bringing the two points indicated by (d'_2, c'_2) and (d_2, c_2) into practical coincidence.

Suppose, for example, that it is desired to ascertain the value of k'' for the usual conditions of a test as given in Table 2, Section 15. The calculation by Equation (207) would then be:

$$
\begin{aligned}
c_2 = c'_2 &= 0.0591; \\
d_2 = d'_2 &= 0.9984; \\
p_2 = p'_2 &= 0.00006; \\
c &= 290. \\
d &= 1.1837; \\
p &= 0.245; \\
\alpha &= 1.397, \text{ as measured from Plate XLVIII.}
\end{aligned}
$$

The point where α is measured lies on the line for 20° temperature, as it is assumed that this was the temperature during the usual test. Therefore, by Equation (207),

$$k'' = \frac{1.1837}{0.9984}\left(1 - \frac{0.245 - 0.00006}{1.397 - 0.00006}\right) = 0.977 \ldots\ldots (208)$$

for the greater portion of the tests.

Observe that the calculation may be made with sufficient accuracy with a slide-rule, provided Equation (207) is slightly changed so as to correspond to the second form of Equations (206).

When distilled water is mixed with strong salt solution of a concentration of about 297 grammes per liter, at a temperature of 20° cent., the following results may be deduced by placing $c_1 = 0$, $p_1 = 0$, and $d_1 = 998.23$, in Equations (206).

TABLE 94.—Values of the Shrinkage Coefficient, k, for Relatively Small Ratios of Mixture of a Salt Solution of 296.98 Grammes Per Liter and Distilled Water at a Temperature of 20° Cent. Computed From the Data of Table 1 and the Following Elements:

$d = 1\,187.9$, $p = 0.25$, $c_1 = 0$, $p_1 = 0$, $d_1 = 998.23$, $d \div d_1 = 1.190$, and $t = 20°$ cent. (calculation by slide-rule).

Approximate value of r	c_2	d_2	p_2	a	k	k''
0.5	197.33	1 127.6	0.175	1.525	0.995	0.999
1.0	148.08	1 096.9	0.135	1.501	0.992	0.997
2.0	101.36	1 067.0	0.095	1.474	0.989	0.994
3.0	73.409	1 048.7	0.070	1.455	0.986	0.992
4.0	57.079	1 037.8	0.055	1.443	0.984	0.990
5.0	51.705	1 034.1	0.050	1.440	0.984	0.988

In computing Table 94, the first of Equations (206) may be put in the following simple form, as c_1 and p_1 are nil: Mr. Groat.

$$k = \frac{d}{d_1}\left(1 - \frac{p}{\alpha}\right) \ldots\ldots\ldots\ldots\ldots\ldots (209)$$

In closing the remarks on shrinkage, it may be of service to observe that, in accordance with the notation used in Equations (206) and (207), and distinguishing between the two corresponding values of α by using prime marks, the relation between k and $\boldsymbol{k}''$ is given by;

$$\boldsymbol{k}'' - k = \frac{d}{d_2}\,\frac{(p - p_2)\,(\alpha'' - \alpha)}{(\alpha'' - p_2)\,(\alpha - p_2)} \ldots\ldots\ldots\ldots (210)$$

As $p > p_2$, $\alpha'' > \alpha$, $\alpha'' > 1$, $\alpha > 1$, and $p_2 < 1$, it follows that $\boldsymbol{k}'' > k$, which agrees with the same conclusion reached in Section 32.

Formulas Depending on Ratios Only, Deduced From Those Depending on Weights.—Remarking further on the theory, it will be instructive to show more of the relations which exist between the various quantities.

By Equations (27), we have, for example,

$$\left.\begin{aligned} f &= \frac{f'}{1 + F'\,x} \\ f' &= \frac{f}{1 + F\,x'} \end{aligned}\right\} \ldots\ldots\ldots\ldots\ldots\ldots (211)$$

where,

$$\left.\begin{aligned} x &= \frac{p_2 - p'_2}{p - p_2} = \frac{1}{\boldsymbol{f}''} \\ y &= \frac{p_2 - p'_2}{p - p'_2} = \frac{1}{\boldsymbol{F}''} \\ x' &= \frac{p'_2 - p_2}{p - p'_2} = -\,y = -\,\frac{1}{\boldsymbol{F}''} \end{aligned}\right\} \ldots\ldots\ldots\ldots (212)$$

etc., $\boldsymbol{f}''$ and $\boldsymbol{F}''$ being, respectively, the ratio of mixture and the ratio of dilution necessary to convert special dilution to the condition of tail-water, in accordance with the definitions and meaning of Equations (14), Section 11, which implies that the special dilution is weaker than the tail-water, or $r' > r$.

But, by Equations (38) and analogy,

$$\left.\begin{aligned} \boldsymbol{F}'' &= \boldsymbol{R}''\,\frac{d_2}{d},\ \boldsymbol{f}'' = \boldsymbol{r}''\,\frac{d'_2}{d} \\ F &= R\,\frac{d_2}{d},\ f = r\,\frac{d_1}{d} \end{aligned}\right\} \ldots\ldots\ldots\ldots (213)$$

etc.

Mr. Groat.

Therefore, by proper substitutions, Equations (211) may be transformed so as to give

$$\left.\begin{aligned} r &= \frac{r'}{1 + \dfrac{R'}{r''}} \\ & \qquad (r' > r) \\ r' &= \frac{r}{1 - \dfrac{R}{R''}} \end{aligned}\right\} \ldots\ldots\ldots\ldots\ldots\ldots(214)$$

thus deriving the relations discussed in Section 35.

It is also possible to deduce these same relations by Equations (78), (90), and (91). Thus, for example,

$$\begin{aligned} r &= R'\, r'' + r' \\ & \qquad (r > r') \\ r &= R''\, r'' \end{aligned}$$

Eliminating r'' and solving for r, we have

$$r = r\,\frac{R'}{R''} + r', \text{ or, } r = \frac{r'}{1 - \dfrac{R'}{R''}} \ldots\ldots\ldots\ldots(215)$$

as before. The remaining relations may be treated in similar manner.

Conclusion.—In closing this discussion, there are a few thoughts which occur to the writer as being worthy of mention.

During the oral discussion, Mr. Wiggin asked for the cost of the tests, with the evident idea that this knowledge would be of value in determining the probable cost of future chemical tests. Unfortunately, the scope of the investigation was so much larger than would ordinarily be undertaken in turbine testing, that a mere statement of total cost without detailed analysis will be of little service for this purpose. The writer would gladly make such a detailed analysis of the cost of the complete series of studies if he thought any useful facts would be brought to light thereby. He feels, however, that this is not the way to arrive at costs. It will be far more satisfactory for the engineer to determine his general method from a study of papers on the subject, afterward arranging the details to suit his own ideas and in conformity with his calculations. His equipment and method for the conduct of the tests thus becoming definite, it will be an easy matter to make accurate estimates of cost. It may be of interest to state that a commercial grade of salt suitable for chemical tests will cost from $1.50 per ton up (depending on the condition of the market), delivered f. o. b. cars, at the salt works.

There are two possible sources of delay and contingent expenses that may exist in connection with turbine tests in place, which it may

be well to mention. Where the purchaser and maker each have the right to undertake investigations of their own during the tests, there are likely to be interferences with each other, which are sure to cause more or less delay and repetition, especially if each has a particular line of investigation differing from that of the other; and, where the tests must be conducted without interfering in any measure with the power-house output, methods become restricted, and this leads to an increase in cost. Mr. Groat.

With the preceding statements in mind, there is no objection to saying that the total cost of experiments and studies involved in the writer's paper was about $18 000. This item includes: The preliminary study; rating current-meters; numerous railroad fares; chemical testing equipment, including tanks, pumps, pipe lines, and laboratory; complete set of precision direct-current electrical testing equipment; complete set of precision alternating-current electrical testing equipment; erecting and adjusting equipment and instruments; supplies and operating expenses in the conduct of the tests; and computations. It does not include the cost of preparing the paper, except in so far as many of the tables are necessarily copies of those derived from the final computations. The writer estimates, roughly, that the value of the instruments and equipment on inventory at the conclusion of the work was $3 500, leaving a net cost of approximately $14 500.

In Section 79, attention is directed to the impropriety of adding the tail-race velocity-head to the elevation of the tail-water before determining the head acting on the turbine. By so doing, the efficiency is made to appear higher than it really is. It is not uncommon to find water issuing from draft-tubes with velocities as high as 15 or 16 ft. per sec. This is equivalent to a head of about 4 ft. If the total head on the turbine was 50 ft., this would cause the efficiency to be overestimated by nearly 9 per cent. If the tail-race velocity were 8 ft. per sec., the head would be reduced by 1 ft. If the head were only 20 ft. in this case, the efficiency would be more than 5% too high. In making contracts, great care should be exercised not to be misled by incorporating this method of introducing an erroneous head, thereby making the computed efficiency too high.

It may be of interest to remark that titrations of salt solution were used in another investigation during the progress of the regular turbine tests. They were used to determine the location of a leak which passed from the bottom of a pond under a dam and into the tail-race of the power-house. The small stream issuing from under the dam could be sampled by simply dipping up the water in a sample container. The strong salt solution was discharged down a pipe from a barrel on a scow which was moved about over the surface of the pond. The pipe was held close to the bottom, and when it was finally placed

Mr. Groat. near the intake of the leak, the titrations of samples taken down stream from the dam quickly indicated the increase of salt in the water.

In another case the location of a leak above a dam was known, and the object of the investigation was to find by means of titrations the subaqueous outlet in the bed of the river below the dam. Thus far, the writer has not received advices of the results.

It may be of value to mention that some time could have been saved in the computations had the calibration of the iron pipette, or tank calibrator, been made in the manner desired by the writer. A large vessel like this, with a contracted pipe or glass gauge at the top, can be calibrated by a scale of temperatures on the gauge so that it can be filled to contain a fixed volume whatever the temperature. This can be accomplished by graduating the scale of temperatures so that each division mark is at the proper elevation for the water surface at that temperature to correspond to the given volume. It is evident, then, for a metal vessel, that the temperature scale will begin at the top and run downward with increasing temperature. Through some misunderstanding, the temperature scale ran upward, the operation, therefore, resulted in a colossal thermometer instead of a convenient calibrator.

In the rules for the chemical laboratory, Section 88, it was said that the proper rate of draft from a burette was about 2 drops per sec. This is scarcely true for all burettes, as the sizes of the tips vary, and this changes the size of the drops. A better rule would state that the proper rate for the draft from an ordinary 75 or 100-c.c. burette is 8 or 10 c.c. per min.

Salt attracts moisture, and is likely to cake and harden when dried. One or two rough drying tests indicated that the low grade of commercial salt used in the tests carried about 6% of moisture. In other cases, a different result might be found.

The color intensity method of chemi-hydrometry should be distinguished from the method of determining mean velocity by observing the time required for color to pass from one point in a system of conduits to another.

The temperature of samples is a very important matter in conductivity tests. However, if the method of special dilutions, or balanced samples, be adopted, the temperature correction will be eliminated.

In constructing the entrance to the outlet from the salt-solution tank, ample sectional area should be provided, else the full capacity of the tank may not be available, owing to the formation of vortices by reason of the high velocities generated. The outlet from the salt-solution tank in the present case was made of about 18 in. of 8-in. pipe, discharging vertically from the flat bottom of the tank into the 3-in. salt-solution supply pipe. In this manner, the water level

in the tank can be drawn to the bottom without creating vortices or admitting air to the supply line. Mr. Groat.

For a number of years the writer has entertained the idea that a wire carrying an electric current could be used to measure the velocity of water. The current of electricity would tend to heat the wire, and the flow of water along and normal to the wire would tend to cool it, or to determine the temperature. The higher the velocity of the water, the lower the temperature of the wire. Therefore, the conductivity of the wire, or its temperature, would be a function of the velocity and, by having a calibrated apparatus for measuring the conductivity, or temperature, the velocity of the water could be determined. It does not appear, however, that much idea of direction of flow could be gained without getting into a very elaborate device. However, it may be well to mention the principle.

Referring again to the cost of turbine tests: This is a purely relative matter. Frequently, tests result in discoveries leading to improvements which pay for the tests many times over. In one case such improvements led to the recovery of a large amount of power at a cost of less than $1 per horse-power increase in capacity. The actual value of the gain was not less than $500 000, and the cost of the tests was only 1% of this value, an insignificant matter altogether. In another case, tests indicated simple changes in draft-chests, which effected a substantial increase in efficiency and power.

Attention has already been directed to the diagram of turbine performance, Plate LXVI. This diagram, it may be explained, gives all the information concerning turbine performance. It may be utilized to compile many kinds of tables which will be useful to designing and operating engineers and power-house superintendents. Such diagrams will be of great value in designing water-wheels to fit electric generators, and the converse. They will also be of great value in making contracts and specifications for turbines, generators, and complete hydro-electric units.

The writer desires to express his appreciation and thanks to Messrs. Eimer and Amend for the chemical equipment used in illustration of the methods of chemi-hydrometry at the time of reading the paper of which this discussion is the conclusion. He also extends thanks to Mr. Hugh N. Davis, who very kindly assisted with the chemical operations on the same occasion.

The reader may have observed that Table 1 shows evidence of small systematic errors in the data from which it was compiled, especially for the weak concentrations. It may be well to bear this in mind when shrinkage becomes important, as a revision of Table 3 and Fig. 1 will doubtless be required when more correct data become available. This may also modify, or possibly negate, the thesis of

Mr. Groat.

Section 24, which states that a molecule of salt always displaces a portion of the water in which it is dissolved, however dilute the solution may be.

It may not be amiss to repeat that the writer considers Table 85, and the corresponding table of aggregates for Tests *N, O, P, Q, R* (Table 93), as showing the possibilities of current-meter work in turbulent water when the records are corrected by composite rating curves. The errors of 1 to 2% among the four methods for the individual tests are due to the fact that meters were not, in the case at hand, compared in one and the same test. The true precision attainable is apparent when all five of a group of tests are treated as a single test.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE FAILURE AND RIGHTING OF A MILLION-BUSHEL GRAIN ELEVATOR

Discussion.*

By E. P. Goodrich, M. Am. Soc. C. E.

E. P. Goodrich,† M. Am. Soc. C. E.—This paper appeals to the speaker more strongly with reference to incidental and exterior phenomena than with reference to the ingenious and eminently satisfactory method used in righting the elevator, which is the primary reason for the paper. Mr. Goodrich.

The first item of particular interest to the speaker is the demonstration that a structure of the size of this grain elevator, when built of reinforced concrete in accordance with the proper design, becomes a monolithic structure capable of being subjected to extraordinary stresses without seriously damaging the building. The settlement and righting of this elevator are almost identical with an experience concerning a grain elevator in Algiers, erected and righted by French engineers.

The moral of this story is an indirect demonstration of the need of caring for reverse moments in all bottoms, and at the points of intersection of bottoms and columns, together with the need for care in the design of columns to resist bending where need is shown. So long as reinforced concrete members were designed after the fashion of those made of timber or steel, difficulty was sure to arise, but, with the wider adoption of the cantilever, difficulties have disappeared and better structures been secured. The speaker has been interested in noting the widening use of the cantilever, even in steel and timber work, and believes that members thus designed are more efficient than almost any other device for the same purpose.

* Discussion of the paper by Alexander Allaire, M. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† New York City.

Mr. Goodrich.

Reverting to the fact of the monolithic nature of large reinforced concrete structures, many instances may be cited of caissons designed for use as foundations for bridges, docks, etc., which have been handled, lifted on one side, tilted, and manipulated in almost any way found necessary without great difficulty.

The second point of interest refers to the earth pressure phenomena described. The wave that was thrust up, perhaps from some deep stratum, can be made the source of information with reference to earth pressure matters, which may prove of value through an analysis of its size, rate of formation, etc., if such data can be made available. For a long time the speaker has been advocating the making of careful explorations of sub-strata under large buildings, going down many feet below the customary foundation depth. Demonstrations of this need, in addition to that afforded by the Canadian Pacific grain elevator, were also mentioned by Robert B. Stanton, M. Am. Soc. C. E., in his discussion* on earth pressure formation in connection with a slide which took place on the Canadian Pacific Railroad within his observation.

The upheaval of the bottom of the Panama Canal is a gigantic demonstration of the same fact. On a much smaller scale, the upheaval of a steam shovel excavation in Cleveland, which occurred several years ago during the cutting through of a street, is pertinent.

It is the speaker's belief that properly made explorations and physical tests of the soil secured will make it possible to prophesy the possibilities of just such failures as occurred in connection with this grain elevator. Where such possibilities are indicated, obviously, engineers can take all needed precautions to prevent their occurrence. This belief has been applied by the speaker in several foundation investigations, and it is equally applicable to the analysis of soil conditions at Panama or Winnipeg. This paper is thus believed to be of wider interest than that covered in its main description of the mechanical methods used in combating the particular difficulty here encountered.

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* *Transactions*, Am. Soc. C. E., Vol. LIII, p. 307.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A REVIEW OF THE REPORT OF CAPTAIN ANDREW TALCOTT CHIEF ENGINEER MEXICO AND PACIFIC RAILROAD EASTERN DIVISION FROM VERA CRUZ TO MEXICO EXPLORATIONS SURVEYS ESTIMATES 1858

Discussion.*

By Messrs. H. M. Taylor and Emile Low.†

H. M. Taylor,‡ M. Am. Soc. C. E. (by letter).§—The writer has had no connection with the Mexican Railway, but has made frequent trips over it while in charge of the construction and reconstruction of parts of the Vera Cruz and Pacific. The Mexican Railway, a typical English product, has the good features common to all the British built lines—good alignment, good roadbed, well-maintained, good stations, good section houses—and the fault of most of them, namely, the sacrifice of grade to alignment. Its curves were not compensated, neither are those of the British lines in Argentina, Uruguay, or Chili. In approaching divides, like that at Ometusco, between the Valley of Mexico and the Apam Valley, on the Gulf slope, the line makes straight for the hills, holding to the valley and taking a 1.50 grade in order to get over the divide, when, by a slight sacrifice of alignment, a 1% grade could have been had, using the slope which Nature provided; or westbound, an 0.50% grade, as has been built on the Interoceanic. This error was repeated at Guadalupe, at Paso del Macho, and at the Metlac Barranca. Considering its date of construc- Mr. Taylor.

* Discussion of the paper by Emile Low, M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† Author's closure.

‡ Empalme, Son., Mexico.

§ Received by the Secretary, May 5th, 1916.

Mr. Taylor. tion, however, and the condition of the Science of Engineering at the time, its location is notable.

There were several revolutions between its commencement and its completion. Mr. Escandon had interests at Cordoba, and none at Jalapa, and naturally he constructed the line where his interests lay. Cordoba, to-day, due to its water-power, has far more freight to offer than Jalapa, and, as stated by Mr. Ingram, it is fortunate that the cost of operation on such grades was not then understood, or the Mexican Railway would have been built *via* Jalapa, and the two lines would have remained one. The Mexican made directly for Mexico and tapped Puebla *via* a branch, which was the sensible thing to do (notwithstanding Mr. Wellington). The percentage of business from Mexico to Vera Cruz was so much greater than that *via* Puebla that adding the cost of the longer haul *via* Puebla to the freight to and from Mexico would have penalized the public in the City of Mexico and north and west of that point beyond any reason.

The proof that Mr. Wellington was wrong in his theory, is seen in the construction, at a much later date, of the line from San Lorenzo to Oriental by the Interoceanic.

It is not the writer's object, however, to discuss these matters, but to bring before engineers who are interested just what was made of the American-built, or rather located, line. In doing this he wishes to state that it has been always his understanding that Mr. Wellington had practically nothing to do with the actual location or construction of the line. The writer was not in Mexico at the time, but has known many Americans and other foreigners who were, some of whom were in position to know. Mr. Wellington was responsible for the route; not that the route had not been looked over before, for the Palmer-Sullivan concessionaires started a line from Vera Cruz to Mexico, built it to Antigua, about 40 km., did some grading between Perote and Limon, still to be seen, and some between Irolo and San Lorenzo, likewise still to be seen.

The writer never knew definitely what stopped this work, but he has been told that it was a complaint by the Mexican Railway of the infringement of its original and perpetual concession of a line between the City of Mexico and Vera Cruz. The Interoceanic was formed of a number of separate concerns such as the "Ferrocarril de Irolo", extending from Mexico to Irolo and later to Iturbe; the Puebla to San Martin Tram line, from Puebla, 40 km. north through the Valle de Nativitas; and the Tram Company from Puebla to San Juan de los Llanos, *via* San Marcos and Virreyes. The latter was bought up and connected by short pieces of line, almost always badly located and badly constructed, because of an unfortunate contract with Don Delfin Sanchez, a promoter, a wonderfully able man in many ways, but who had no knowledge of railroad operation. Also, his contract was at a

fixed price per kilometer, and, naturally, it was to his interest to fit the grade to the contours as nearly as could be done. Mr. Taylor.

Between Virreyes and Rubin, the Interoceanic was constructed through a wide valley, and a tangent for the whole distance was an easy proposition. One can see from Limon to Oriental with absolutely nothing in the way of a water-grade tangent. Through this the line zigzagged, up over a hill and down again, got a little nearer Tepeyahualco, a small Indian village, on basalt rocks, not worth a car of freight per week twenty years after the line was built.

From Limon to Rubin the line was fairly good, with an ascending grade of 0.73, and 2° curves. The same extended east nearly to Rio Frio; here, rough country was encountered, and a succession of grades up and down, 2.50% in both directions, with maximum curves at the top and bottom of each grade. The line ascended 38 m. to La Cima, and ran down again to Las Vigas, the natural summit of the country, the distance being 15 km. A revision of the line, built while the writer was in charge, reduced the grade to a supported 0.35 and a maximum curve of 3 degrees. The line was shortened $1\frac{1}{4}$ km., and, in this short distance, more than 1 100° of curvature were eliminated. The quantities of the revision were nearly three times those of the original line, but the cost was very nearly the same, due to the fact that nearly all the original line was in rock, and the revision was nearly all in earth.

In operation, the revision cut down the helper-engine distance 28 km.; trains in both directions were helped, and the estimate showed more than 20% per annum on the cost of making the change.

The line from Metepec to San Lorenzo was worked out on the basis of ton-kilometer cost, and when revision was made, the net returns to the Company were estimated as being more than 15 per cent. An examination of the returns of the Company after these revisions were made showed that the estimates were conservative.

Below Las Vigas the line descends on a 2.50% grade to Banderilla; then there is a light grade crossing over into another drainage, with a 2.50% adverse grade to above Bruno, descending again on a 2.50% grade to Jalapa. This work of revision was heavy, and business did not yet justify the change there. It was close at hand in 1911, however, together with that to Las Vigas. The writer disagrees with Mr. Ingram in believing that the Company, having made two investments which proved so profitable, will not make another along the same lines when peace happily returns to Mexico.

Below Jalapa, the revision showed that the old Camino National, along which the Mexican Tramway ran in Mr. Wellington's time, was the proper route, a 2% line with a maximum curve of 6° being found and compensated. The tonnage was calculated, and the quantity required to make the investment in the change of line profitable was

Mr. Taylor. determined. That, too, was not so far away when the Madero Revolution caused postponement of the question of investments in all Mexican projects excepting oil lands.

Unlike Mr. Ingram and others, of the Mexican Railway, the writer is not proud of the location of the Interoceanic. It is a fine property, and it is to be regretted that its location renders it inferior to the Mexican line as a transportation machine, when it could have been superior, as no doubt it will be when peace comes, prosperity returns, and it is made of standard gauge.

Mr. Low. EMILE LOW,* M. AM. SOC. C. E. (by letter).†—On March 4th, 1517, Francisco Hernandez de Cordoba discovered the coast of Yucatan, and in the following year Juan de Grijalva landed on the island now occupied by the castle of San Juan de Ulua, off Vera Cruz. On April 21st, 1519, Hernando Cortez landed on the site of the present city of Vera Cruz. On August 16th, 1519, Cortez and his bold Conquistadores left Cempoalla, the capital of the Totonac Indians, on his famous march to the Aztec capital, Tenochtitlan, the site of the present City of Mexico. His force consisted of 400 Spanish soldiers, 15 horses, with 7 pieces of artillery, augmented by several thousand Totonac Indians.

The line of march passed through the Indian village of Jalapa, thence to the north of the volcano, Cofre de Perote, reaching the table-land, across this to the Indian town of Tlaxcala, where a battle was fought with the natives, in which the Spaniards were victorious. From this place the march continued to Cholula, where another battle was fought between the Conquistadores and the Cholulans, in which several thousand of the latter were slain. The ascent of the mountain then began, Cortez crossing the saddle between the volcanoes of Popocatepetl and Iztaccihuatl, descending to the town of Amecameca, and then across the valley to the capital of Montezuma which was entered November 8th, 1519, less than 3 months after leaving the shores of the Gulf of Mexico.

It is hard to believe that the route traveled was anything more than a trail, perhaps the only one between the capital and the Gulf of Mexico, a foot-path only. There were no horses in the country, and wheeled vehicles were unknown. Horses were brought to Mexico by the Spaniards and during the two centuries which succeeded the Conquest, the journey between the coast and the interior was made on horse, or mule back, or on foot. At the beginning of the Nineteenth Century, litters (*literas*) were used between Vera Cruz and Jalapa, and a line of coaches ran thence to the capital. In 1833 the first stage line was established between Mexico and Jalapa, and was extended later to the coast.

* Buffalo, N. Y.

† Received by the Secretary May 2d, 1916.

As streams flowed in an almost direct line from the top of the table-land to the coast, making the shortest descent, which was the reason for the first line of communication chosen. If there was another one, or more, the fact was not known at the time. Later, another trail was developed to the south of Orizaba, and still later, at about the end of the Eighteenth Century, they were transformed into wagon roads, with the dignified name of *camino real,* the King's highway. Mr. Low.

On page 2572* these two highways between Vera Cruz and the City of Mexico are mentioned. The northern, passing to the north of Cofre de Perote, built at the expense of the Consulate of Mexico and constructed with Roman splendor, to serve as a passage for all the traffic carried on by New Spain at one period, was abandoned shortly after the Independence (1823). Its towns, which were maintained by a fictitious commercial movement, were depopulated little by little, and its fields were deserted.

The National or King's bridge—Puente del Rey, as it was called during the colonial period—56 km. out from Vera Cruz, was constructed toward the end of the Eighteenth Century by Gen. Don Manuel Rincon. In its material aspect it had the appearance of a Roman viaduct, and the structure was executed not only scientifically, but with splendor, as it changes its direction to follow the course of the road.

When Capt. Talcott landed in Vera Cruz, in January, 1858, he found the conditions as stated. From the examinations made by him, he decided that the proper line for a railroad was *via* Orizaba, and his surveys were all based on this decision.

Subsequent events absolutely justified this action, and it would have been nothing less than a national calamity for Mexico had the Jalapa route been chosen at the time.

About 1873, Don Ramon Zangroniz, of Vera Cruz, obtained a concession for a tramway from Vera Cruz to Jalapa, to be operated by animal power. He succeeded in building only a short section of it, when, in 1874, the concession was transferred to the Mexican Railway Company, Limited, which continued and completed the construction in May, 1875.

This horse tramway actually began at the Tejeria station, 15 km. out from Vera Cruz on the Mexican Railway, and then continued in a straight line to San Juan, where the main highway (which passed north from Vera Cruz) was intersected and generally followed to Jalapa, passing through the towns and villages of Zopilote, Tierra Colorada, Paso de Ovejas, Puente Nacional, Rinconada, Plan del Rio, Cerro Gordo, and Dos Rios, the distance between Vera Cruz and Jalapa being 114 km. (71 miles), with a rise of 1 361 m. (4 465 ft.),

* *Proceedings,* Am. Soc. C. E., for December, 1915.

Mr. Low. of which 1 100 m. (3 608 ft.) are made between Rincon-Revolu- Jalapa, a distance of 50 km. (31 miles), an average graull Mexican although it is stated that 10% grades abound, which statement needs verification.

This tramway, extending for more than 70 miles, was the longest horse railway in the world.

The late A. M. Wellington, M. Am. Soc. C. E., landed in Vera Cruz in March, 1881, and it may not be amiss to state here that the writer and his father, Sigismund Low, were fellow travelers on the same steamer from New York, having secured service with the Mexican Central Railway, then under construction between the City of Mexico and El Paso del Norte (now Ciudad Juárez), while Wellington and his principal assistant, the late H. H. Filley, M. Am. Soc. C. E., were employes of the Mexican National Railroad, a narrow-gauge line building between the City of Mexico and Laredo on the Rio Grande. As stated by Wellington,* his first assignment was to make a reconnaissance for a railroad line from Vera Cruz to Mexico, *via* Jalapa "sufficient to determine the general possibilities of the route" and on which a corps of engineers was already engaged. The reconnaissance made by Wellington occupied only 3 days, and the resulting report was "that a 2 per cent. grade (uncompensated) was practicable". Such a conclusion was easily arrived at, as all the necessary data were available. The natural topography of the country was such, that a 2% grade (uncompensated) just fitted it, although it was necessary at a number of points to use an excessive development of line in order to maintain this low grade. It may be pertinent to ask here why Wellington called this line, the "American Line". He, like many other engineers not familiar with railroad building in Mexico, labored under the belief that the Mexican Railway (Vera Cruz-Mexico) was surveyed, located, and constructed by English engineers, when the very opposite was true, that honor belonging to an American engineer, Capt. Andrew Talcott, whose name and fame is indelibly connected with it.

Some time after Wellington's reconnaissance, further surveys were made, which showed a rise of 7 323 ft. in 72.64 miles. Wellington then made a comparison of his line with that of the Mexican Railway, and, regarding their respective grades, says:

"Continuous 2 per cent. (uncompensated) against a broken 4 per cent. (uncompensated); including the effect of curvature or of compensation therefor, 2.6 per cent. against 6 per cent."

It is hard to understand what method of computation was used in arriving at the comparative rates of grades, after allowing for com-

* "The American Line from Vera Cruz to the City of Mexico, via Jalapa, with Notes on the Best Methods of Surmounting High Elevations by Rail," *Transactions*, Am. Soc. C. E., Vol. XV, p. 791.


RAILROAD LINES
BETWEEN VERA CRUZ AND MEXICO
MEXICAN via ANCHA
INTEROCEANIC via ANGOSTA
SCALE OF KILOMETERS
10 5 0 10 20 30 40 50
GULF OF MEXICO
VERA CRUZ
PUEBLA
TLAXCALA
HIDALGO
MEXICO
MORELOS
Mexico
Lake Texcoco
Texcoco
Pachuca
Tulancingo
Zacatlan
Chignahuapam
Apizaco
Puebla
Tlaxcala
Malintzi
Ixtaccihuatl
Popocatepetl
San Marcos
Esperanza
Pico de Orizaba
Orizaba
Cordova
Jalapa
Cofre de Perote
Perote
Teziutlan
Huatusco
Vera Cruz
Boca del Rio
Anton Lizardo
Alvarado
Tlalpam
Amecameca
Atlixco
Tecali
Tepeaca
Matamoros
Maltrata
Soledad
Paso del Macho
Tamarinda
Los Negritos
Paso Obispo
Medellin
Ozumbilla

pensation. Wellington allowed for his line, in which 20° curves occurred, a rate of 0.03 ft. per degree, which would give 0.6 ft., or an equivalent 2.6% grade. For the Mexican Railway, he assumed a rate of 0.11% which would give 2.0 ft., or an equivalent 6.0% grade, certainly a most extraordinary method of calculation. With the same rate of curve compensation, the equivalent grade would have been, on the Mexican Railway, 4.5 per cent. Mr. Low.

After a short connection with the Mexican National Railroad, Wellington returned to the United States, but soon after entered the service of the Mexican Central Railway, and, during his connection with this railway, 1881-83, he was an ardent advocate of 2% grades, under all conditions, very high curve compensation, and momentum grades, which requirements did not always fit every line, as was shown in the case of the Guanajuato Branch-Siloa-Marfil, in which the writer, under his father, was in charge of location and construction.

The original survey for this branch line was from a point between Irapuato and Siloa, following the valley of the Guanajuato River to the city of the same name. This would have placed the junction in an undeveloped plain, and Siloa was finally selected. To reach Guanajuato from this city it was necessary either to tunnel a high foot-hill or go over the top. A 3% grade just fitted the topography, and the line was thus located. Wellington ordered a 2% grade with high curve compensation, which, starting with a shallow cut at the summit, brought the line on reaching the main valley "high up in the air", necessitating much development to get down, and almost doubling the distance. It is needless to say that this low grade line was abandoned and the 3% line built.

The present Mexican Railway was incorporated on August 20th, 1864, as the Imperial Mexican Railway Company, Limited, under the government of Emperor Maximilian, being granted a subvention (concession or subsidy) of $560 000 a year, of which $420 000 was the property of the company for 25 years dating from November 11th, 1868.

The Mexican Government also agreed not to subsidize any other railroad between Vera Cruz and the City of Mexico for 65 years from November, 1868.

The railroad *via* Jalapa, 3-ft. or narrow gauge, was subsequently built under the name of the Interoceanic Railway, a link in the present National Railways of Mexico.

It was chartered on April 30th, 1888, and purchased all the concessions granted by the Mexican Government for a railroad from Vera Cruz to Amacusac (near Puente de Ixtla) *via* Puebla and the City of Mexico. The main line *via* Puebla was opened from Mexico to Vera Cruz on April 1st, 1891, the distance being 339 miles.

Above and below Jalapa there are 3% grades. Later, about 1905, a cut-off was built between San Lorenzo and Oriental, 72 miles,

Mr. Low. which reduced the distance to 293 miles between Vera Cruz and the City of Mexico, as compared with 264 miles *via* the Mexican Railway.

The map, Plate XI, shows the lines of the Mexican and Interoceanic Railways between Vera Cruz and the City of Mexico.

The especial feature shown on this map is the more favorable alignment of the Mexican Railway, the sinuosities of the Jalapa line being very pronounced.

The highest elevation of the Maltrata grade on the Mexican Railway is between Boca de Monte and Esperanza, it being 2 470 m. (8 104 ft.) (although there is a slightly higher elevation, just east of San Andres, 2 485 m. (8 153 ft.) and on the Interoceanic at La Cima, the elevation is 2 465 m. (8 087 ft.). There are descents on the former line aggregating about 130 m. (426.5 ft.), probably somewhat less on the latter line, so that the sums of the ascents and descents are a little in favor of the Jalapa line.

Regarding the highest elevation between Vera Cruz and the City of Mexico, Hacienda de Acocotla, between Apizaco and Huamantla, on the Mexican Railway is 2 537 m. (8 323 ft.) and, on the Interoceanic, Mena is 2 568 m. (8 425 ft.).

For a number of years, and likely now, all competitive traffic, both import and national, has been pooled by the two competing lines.

In reference to the report of Mr. Pascual Almazan on a line *via* Pueblo Viejo, Octitlan, Ixhuatlan and San Juan Coscomatepec, it will be noted on the map, Plate XI, that the Mexican Railway has since built a railroad from Cordoba to the latter town. Thus, it will be seen that many of the railroad lines follow the old trails, which proves that to some extent the Indian was the pioneer engineer.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

COHESION IN EARTH: THE NEED FOR COMPREHENSIVE EXPERIMENTATION TO DETERMINE THE COEFFICIENTS OF COHESION

Discussion.*

By Messrs. E. P. Goodrich and William Cain.†

E. P. Goodrich,‡ M. Am. Soc. C. E.—The speaker desires to commend the author for his plea for clearer thinking and for more careful analysis of physical phenomena connected with earth pressures, but does not believe that the point raised with reference to internal friction is of material moment, even though there may be theoretical reasons which lead to a possible division into sliding friction proper and cohesion. The author points out that unit cohesion will probably be found to increase with depth, and is, therefore, variable. In his discussion of the element of friction, he also suggests that a variation may occur. Should it be found that these two elements vary according to different laws, it may conduce to clarity of thought to analyze them separately; but should the laws of variation be found to be practically identical, or the amount of variation in one case or the other very slight, then there appears to be no practical reason for not using a single element to include both factors and including both in a common term. For the sake of clarity, the term "angle of internal friction" seems to the speaker to be as good as any. Mr. Goodrich.

It is not understood that the author objects to the internal friction theory as applied to many other materials, as it would seem impossible

* Discussion of the paper by William Cain, M. Am. Soc. C. E., continued from April, 1916, *Proceedings*.

† Author's closure.

‡ New York City.

Mr. Goodrich.

that such could be the case on the part of any one who has studied with care the analysis made by Professor Basquin in a paper* before the Western Society of Engineers in 1912. The fact that results of such marked concordance can be secured when computed by the theory of internal friction (ignoring cohesion), in comparison with tests, leads to the conclusion that the separation, suggested by the author, between sliding friction and cohesion is probably unnecessary. Table 4 which illustrates this concordance of results, has been computed by Professor Basquin.

TABLE 4—Angle of Rupture.

Material.	Angle.	
	Observed.	Computed.
Cast iron, Specimen *A*	54.8°	55 3°
" " " *B*	55	53.4
Limestone	62.2	61.7
Asphalt paving brick	59.7	58.6
Milwaukee brick	58.2	58.5

The diagrams in Professor Basquin's paper, with reference to the principal stresses developed in thick cylinders, according to the theories of internal friction, maximum principal stress, maximum principal strain, and maximum shearing stress, show such a striking concordance with fact in the case of the results computed by the theory of internal friction (ignoring cohesion), that the author's suggestion would seem to be of small weight. Finally, Professor Basquin's use of the diagram of circular stress in analyzing one of the experiments on bank sand, reported in the speaker's paper on "Lateral Earth Pressures and Related Phenomena",† discloses the relative importance of cohesion and sliding friction in the case of that earth, and with a uniformity of result which is believed to go far toward demonstrating the fact that internal friction is the largest factor in earth pressure phenomena, and that a knowledge with regard to this will make possible a fairly accurate analysis of earth pressures.

The speaker heartily agrees with the author's suggestion that the Special Committee of the Society which is making investigations of earth pressure matters should have placed at its disposal a properly equipped laboratory, if it is to do any work of value.

It is not understood that a recommendation is made as to any special testing scheme, the special device suggested by the author having been found, more than 12 years ago, to be inadequate to

* "The Circular Diagram of Stress and Its Application to the Theory of Internal Friction", *Journal*, Western Soc. of Engrs., Vol. XVII, p. 815.

† *Transactions*, Am. Soc. C. E., Vol. LIII, p. 272.

secure accurate results, the speaker turning finally to his testing cylinder, because it provided results which were not approached, with regard to consistency and sensitiveness, by any other device. The results of these tests with the sliding boxes, in experiments on clay, were found to be extremely difficult of interpretation. Plastic clay is almost viscous in its action, so that motion of the boxes commenced under very small stresses and actually attained a visible velocity with increases of load, even before the one at which a proper break occurred and sliding friction was developed. Mr. Goodrich.

Difficulties of other kinds were also encountered in the use of the boxes, which were not susceptible of being overcome by the speaker. The sensitiveness necessary in any apparatus is illustrated by the fact that his early experiments were made with cigar boxes filled with sand, and the angle of friction was measured by tilting the boxes until one slid over the other. It was found that when the first two boxes used (which were, respectively, 3 and 5 in. deep) were reversed in position, the angle of tilt at which sliding took place differed. Such a sensitiveness to load conditions was susceptible of careful determination only with accurate testing machinery, and, in consequence, the cylinder was developed. In the early experiments with the latter device, it was found that infinitesimal displacements of the soil particles produced marked changes in internal stresses.

It was thus proved indispensable that some device should be invented which would maintain internal stress and strain conditions with practical exactness. The electrical device finally installed made this possible, and it is interesting to note that the Government, in its testing experiments, has not yet been able to improve the speaker's type of design of apparatus so as to increase its sensitiveness materially. Earth is elastic to a certain extent, and as long as the strains are within this very minute elastic limit (the existence of which experiments have demonstrated), it is probable that stress changes, which are materially different from those in the earth mass in its virgin state, do not take place. The analysis of the work done by the speaker is believed to demonstrate that the experiments with the cylinder, when analyzed by means of Rankine's formula, will give the angles of internal friction (using the word in the sense deprecated by the author), and that a series of such tests under varying pressures, when plotted in accordance with the scheme developed by Professor Basquin, will give what the author desires, *viz.,* both sliding friction and cohesion.

In passing, it is interesting to note that the author, in his very interesting paper on "Stresses in Wedge-shaped Reinforced Concrete Beams",* used the very term, "internal friction", which he condemns in this paper. He should doubtless be forgiven, because each has the

* *Transactions,* Am. Soc. C. E., Vol. LXXVII, p. 745.

Mr. Goodrich. privilege of changing his mind, but it seems to the speaker that the expression is both appropriate and descriptive, and that it will hardly be surrendered, because of a more or less theoretical idea that the internal phenomena combine two variables. The speaker wishes to repeat most emphatically his statement of belief that it is absolutely necessary to secure a vast amount of adequate information in regard to soils of all kinds. To this end it is hoped that the Special Committee of the Society will be given every opportunity to make extensive and exhaustive experiments.

Mr. Cain. WILLIAM CAIN,* M. AM. SOC. C. E. (by letter).†—Both Mr. Richardson and Mr. Green refer to the definition of cohesion as given in the Century Dictionary. This definition appeals perhaps more to some physicists than to the engineer. The writer has always had in mind the following definition, as given in the Standard Dictionary:

"Cohesion is that force by which molecules of the same kind or of the same body are held together, so that the body resists being pulled to pieces. * * *

"The distinction between *cohesion* and *adhesion,* once insisted upon strongly, is not now generally regarded as fundamental. Some physicists have limited *cohesion* to particles of the same kind, others to those of the same body. Thus the force that holds the mica to the feldspar in granite would be called *cohesion* by some, and *adhesion* by others."

As is evident from this definition and the accompanying comments, the word "body" can refer to a heterogeneous mass, as a mass of earth, or a granite rock consisting of quartz, feldspar, and mica, and it is plain that there is authority—even among physicists—for the statement that any heterogeneous mass of earth may be endowed with cohesion.

Certainly, as far as the writer knows, engineers have always held this view, evidently for the reason that they are principally concerned with the resistance to sliding of the earth along a plane, and, to a limited extent, to its tensile resistance, the word "earth" referring to clay or to any heterogeneous mixture of sand or gravel with clay or clayey matter, and perhaps humus, with more or less moisture. At one extreme, we may have nearly clean, dry sand with very little cohesion; at the other extreme, pure clay with a large cohesive resistance. In fact, clay and consolidated earth act like a solid in being able to resist both tensile and shearing forces; but they differ from a solid (as iron) in this, that their elasticity is null or imperfect, and their properties vary very greatly with the heat and moisture present, with the consequent freezing and thawing, and the chemical changes that may occur. The properties of earth are likewise affected

* Chapel Hill, N. C.

† Received by the Secretary, June 9th, 1916.

by vibration due to heavy moving trains or vehicles, so that, in consequence of the various influences cited, the time element comes in, which thus differentiates it from a solid, such as steel when properly protected from chemical changes. Mr. Cain.

The term "cohesive resistance" of earth may properly apply either to its tensile resistance or to its resistance to sliding along a plane in the earth, dependent on the viewpoint. However, as the tensile resistance of the earth is rarely called for, the term "cohesive resistance of earth", from Coulomb's time to the present, has been generally restricted to mean the resistance to sliding as affected by cohesion, exactly as given by Coulomb's two laws and the resulting Equations (1) and (2), referring to Fig. 1.

As previously stated, these two laws are still on trial, but, as far as experiments go, they are practically sustained. Thus, the results of the first series of experiments of MM. Jacquinot and Frontard, as given by the readings, when reduced to English weights and measures, are as follows:

Normal load, p_n, in pounds per square foot.	Tangential force causing rupture, q, in pounds per square foot.
692	492
2 980	837
5 665	1 196
7 154	1 450

Here p_n and q, the observed quantities of the experiments, have the meanings previously given.

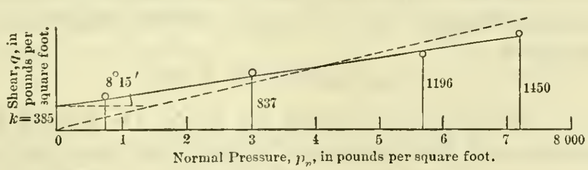

FIG. 2.

On plotting the values of p_n as abscissas, and the corresponding values of q as ordinates, as shown in Fig. 2, it is found that the straight line,

$$q = p_n \tan. 8^\circ\ 15' + 385,$$

very nearly passes through the plotted points. On comparing with the equation,

$$q = p_n \tan. \phi + k,$$

it is seen that $\phi = 8^\circ\ 15'$, and $k = 385$ lb. per sq. ft. (cohesion). Résal, in Table 1, assumes $\phi = 8^\circ$, and computes the corresponding values of k from the last formula, for the simultaneous values of p_n

Mr. Cain. and q observed. The method just outlined seems to the writer to be more satisfactory in its results. In this first series of experiments, the cakes or pats of earth experimented on were very moist, but the apparatus was in order and the results were considered reliable.

In the next series of experiments, the manometers were out of order, and a large correction had to be applied; hence the results are open to doubt, and may not be reliable. The cakes were taken directly from the earthen dam, and they contained "the minimum quantity of water compatible with plasticity". The results are as follows:

Normal load, p_n in pounds per square foot.	Tangential force causing rupture, q, in pounds per square foot.
3 057	1 036
5 479	1 356
7 740	1 941
9 921	2 288

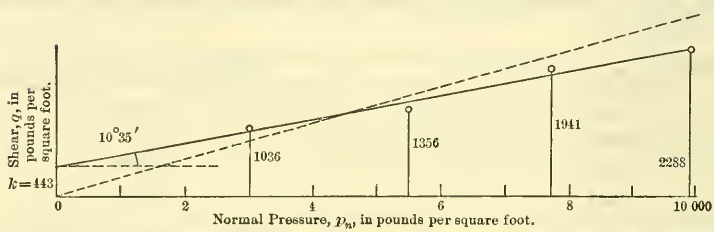

FIG. 3.

The simultaneous values of p_n and q are shown by Fig. 3, and it is found that the straight line that nearly fits the experimental results has the equation,

$$q = p_n \tan. 10° 35' + 443,$$

whence $\phi = 10° 35'$, and $k = 443$ lb. per sq. ft. On plotting to a large scale, the value of k (the intercept of the straight line on the axis of q) and the inclination of the line can be found with all desirable accuracy.

Referring now to Mr. Bell's experiments, of which only a brief summary has been given, it was found by Mr. Bell, in all the experiments on eleven different classes of soils, mainly of clay, that a straight line fitted the plotted results very well in every instance, and, further, that in no case, except for perfectly dry sand, did the straight line pass through the origin; hence the graphs, Figs. 2 and 3, are typical of the results of the experiments thus far performed, and the two laws of Coulomb, with the resulting Equations (1) and (2), seem to be verified.

It will be observed, therefore, for ordinary (clayey) earth or clay, whether pure or impure, that the graph never passes through the origin, and that the equality, $q = p_n \tan. \phi$, referring to earth

endowed with friction but without cohesion, is never fulfilled. The graph of $q = p_n$ tan. ϕ' (where $\phi' > \phi$) is shown by a dotted line in Fig. 2, or Fig. 3, and such a line never represents the facts for the materials in question. The attempt to use such a line as a sort of average for the application of the ordinary theory of non-coherent earth would prove futile, because, if x is the abscissa of the intersection of the two lines, Mr. Cain.

$$q = p_n \text{ tan. } \phi' \text{ and } q = p_n \text{ tan. } \phi + k,$$

it is seen that when $p_n < x$, the value of q given by the first equation is too small and when $p_n > x$, it is too large. Thus, along a plane of rupture, the resistance to sliding would not be given correctly by the first equation for any value of p_n other than x. From all that precedes, it is evident that the statement of Mr. Green, that, in Fig. 1, "the ratio of Q to P_n is the coefficient of static friction of the material tested" is untenable, and that any attempt to apply such a conception to the case of earth endowed with cohesion as well as friction, is doomed to failure.*

The writer is glad to note that Mr. Richardson agrees with him that a more intimate contact of the particles should increase the coefficient of cohesion for a given earth, but he is of the opinion that the increase is not so much a function of the total surface of the particles as of the area of their actual contact along the plane of sliding. However that may be, the engineer is more especially interested in the experimental values.

At first sight, from examination of Figs. 2 and 3, the assumption does not seem to be realized, but it is possible that the results have not been interpreted aright. In fact, Résal suggests, in connection with the results pertaining to Fig. 3, that possibly, if ϕ was assumed equal to 8° 32′ (tan. $\phi = 0.15$) and the successive values of k are computed from the equation, $k = q - p_n$ tan. ϕ, giving 578, 533, 780, 799 lb. per sq. ft., corresponding to the increasing values of p_n previously given, that the (generally) increasing values of k might represent more nearly its true values.

So far as the value of q (the vital thing in earth pressure theory) is concerned, either method leads practically to the same value of this factor; so that the theory of earth pressure, which is based on the constant values of ϕ and k, as found in Fig. 3, is seen to be valid.

The supposed increase of k with the normal pressure received a striking confirmation in experimenting with the earth after it had been energetically rammed for 4 hours, when it was found that the coefficient of cohesion had about doubled.

* The theory of coherent earth is complicated, but the writer, in his "Earth Pressure, Retaining Walls and Bins" (recently published by John Wiley and Sons), has been enabled, by aid of Mohr's "Circular diagram of stress" to develop it in the simplest and most practical manner. It is thus available whenever the coefficients, $f =$ tan. ϕ and k for the particular earth, have been ascertained by experiment.

Mr. Cain. The engineers likewise subjected the cakes or pats of earth to lateral unit pressures, two and three times as much as the normal unit pressures, the lateral pressures being exerted for an hour, then released and repeated, to consolidate the pat more thoroughly. As a result, the cohesion was found to have increased 60%, if tan. ϕ is assumed to be equal to 0.17 ($\phi = 9° 39'$).

It is a matter of great practical importance to know how to increase the coefficient of cohesion, and these experiments indicate that ramming, with use of water, will effect a material increase. With filling behind a retaining wall, well rammed and thoroughly drained, as in Mr. Lindenthal's design previously noted, the thrust of the earth should be materially decreased, and there is every prospect that the decrease may be permanent.

The writer has read with great interest the "Progress Report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations",* in which the classification of soils has been done in a scientific manner, and will afford a working basis for the complete investigation of their properties, which it is to be hoped, will be carried forward, with liberal aid from the Society, to a successful conclusion. The "water content" of soils is often very loosely described, and, for definiteness, it is desirable that the tentative classification† of the Special Committee on Soils be adopted, at least, temporarily.

The report of the "U. S. Bureau of Standards Sub-Committee", on Earth Experiments and Apparatus,‡ leads one to hope, from the thorough manner in which the preliminary testing of gauges, etc., is being done, that reliable practical results may be forthcoming. The wall friction, possible arching of the material in confined spaces, and even minute movements of the earth particles next the diaphragm, are bugbears to the experimenter; all of which are being investigated carefully by the Sub-Committee.

In this report, the rotating gauge, Fig. 1 (c),§ particularly appealed to the writer, because it seems to offer a very promising method of determining the simultaneous values of f and k for any earth. Thus, let the circle, Fig. 4, of radius r, represent the rotating disk in place, its cup-like top being filled with earth, which, in the rotation, rubs against the earth in the cylinder above it, the surface of sliding being a horizontal plane the area of which is that of the circle $= A$, say. If the earth in the cylinder is

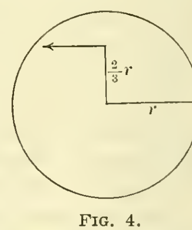

FIG. 4.

* *Proceedings*, Am. Soc. C. E., for March, 1916, p. 343.

† *Ibid.*, p. 347.

‡ *Ibid.*, p. 353.

§ *Ibid.*, p. 356.

subjected to pressure, and this is distributed uniformly and acts normally to the circular top of the rotating disk, with intensity, p_n, the total normal pressure is $p_n\ A$, and the total frictional resistance to the movement is $p_n\ Af$. By a well-known theorem, the sum of the moments of all the elementary frictional resistances about the center of the circle is precisely the same as if the total frictional resistance was concentrated at a point distant $\frac{2}{3}\ r$ from the center. Precisely the same reasoning shows that the sum of the moments of all the resistances due to cohesion is the same as if the total cohesion, $k\ A$, on the circular area, was concentrated at a point distant $\frac{2}{3}\ r$ from its center. Mr. Cain.

Consequently, if M is the torque or moment, due to the external force, about the center of the circle,

$$M = (p_n\ A\ f + k\ A)\,\frac{2}{3}\,r\,;$$

or,

$$q = \frac{M}{\frac{2}{3}\,r\,A} = f\,p_n + k = p_n \tan.\,\phi + k.$$

Now, this is precisely of the form of Equation (2), so that when various experimental values of q for varying pressures, p_n, have been found, they may be plotted to scale, exactly as in Fig. 2, and probable values of $f = \tan.\,\phi$ and k may be read off from the resulting graph.

In the foregoing investigation, the thin rim at the top of the revolving disk has been treated as if it was so much earth. If r is regarded as its inner radius, which is that of the upper surface of the earth that revolves, then the right member of the equation before the last, represents the moment of the earth resistance. To this must be added the moment of the friction of the top of the metal rim on the earth above, $p_n\ A_1\ f\ r_1$, if A_1 is its area and r_1 is its mean radius; so that the last equation is replaced by,

$$q = \frac{M - p_n\,A_1\,f\,r_1}{\frac{2}{3}\,r\,A} = p_n \tan.\,\phi + k,$$

which is correct for the assumptions made. This apparatus, in operation, causes a lateral pressure to be exerted on the earth corresponding to the normal pressure. It thus corresponds to the actual conditions in a mass of earth subjected to its own weight, or loaded uniformly. To a certain extent, this is true for the apparatus suggested in Fig. 1, but in this there can be no lateral pressure along the edges of the surface of rupture; so that in this respect the former apparatus is

Mr. Cain. superior. It is superior, too, in giving a precise area for the surface of rupture, which cannot be said of Fig. 1, because the earth may spread beyond the confines of the boxes or plaques in which it is placed. However, the results for the plaques are not dependent on a uniform normal pressure, or unvarying coefficients, f and k, along the surface of rupture, because average values for p_n, f, and k are perhaps admissible in Equation 2; but, in the case of the rotary disk, the formula deduced is only compatible with a perfectly uniform distribution of normal pressure and for earth with constant coefficients of friction and cohesion over the whole surface of rupture. Thus, both devices have their drawbacks, and one should be used to check the other.

It is stated that Collin determined the shearing resistance of clay and then afterward, by some independent method, found its coefficient of friction. The writer is unable to see how this latter coefficient can be ascertained with any accuracy by any independent method, and he desires to emphasize the importance of determining the coefficients, f and k, from the same sets of observations as illustrated in the foregoing. In this way, and in this way only (as far as one sees), will the conditions correspond exactly to those in an actual filling behind a wall, or in a mass of earth, or a bank of any character.

In conclusion, it may be added pertinently, that the Society is extremely fortunate in having a highly trained body of scientists, like those connected with the U. S. Bureau of Standards, to undertake this exceedingly difficult subject of pressures in earth. It is needless to say that the writer is much gratified at their quick response to his call for extensive experimenting along the lines indicated in the paper.

The writer has read the discussion by Mr. Goodrich and has also reread the account of Mr. Goodrich's experimenting referred to,* and fully appreciates his efforts to advance our knowledge of the subject of earth pressure. He believes, however, that a satisfactory theory for ordinary earth must include the influence of cohesion, and that the discordant results found by Mr. Goodrich with different sorts of apparatus may be harmonized when cohesion and all other modifying influences are considered.

Thus, in Fig. 39 of Mr. Goodrich's paper (reproduced herein as Fig. 5), showing one box, with open top and bottom, on top of another with open top and closed bottom, both boxes being filled with earth, on top of which is a weight, it is seen that much of this weight is transferred by friction and cohesion to the sides of this upper box. If no weight is supposed, still, quite a percentage of the weight of earth in the upper box is carried by its sides. In fact, Leygue found,† for a

* *Transactions*, Am. Soc. C. E., Vol. LIII (1904), p. 272.

† See the writer's paper on "Experiments on Retaining Walls", *Transactions*, Am. Soc. C. E., Vol. LXXII (1911), p. 414.

Mr. Cain.

box without a bottom, about 4 in. square in cross-section and 4 in. high, for heights of sand in the box varying from 1.2 to 3.5 in., that from 0.21 to 0.35 of the weight of sand in the box was transferred to the sides of the box. The case is analogous to that of the bin filled with sand, as to which, hundreds of experiments have shown that a part of the weight of the contained material is carried by the sides, and this proportion becomes very large for deep bins filled to the top. In such cases, the weight of earth with its load (if any) causes a lateral thrust which induces the friction on the walls, and this, with the cohesion there (if any), gives the total vertical component of the reaction of the walls. The arching effect of grain in glass bins has been observed by Mr. Ketchum.*

MODEL FOR DETERMINATION OF COEFFICIENT OF INTERNAL FRICTION.

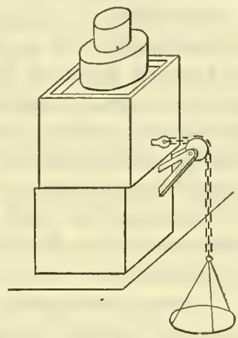

FIG. 5.

Now, recurring to the apparatus, Fig. 5, the weight transferred to the sides of the upper box, does not seem to have been considered by Mr. Goodrich, which invalidates his conclusions, so far as they refer to the experiments performed with this apparatus.

Another source of inaccuracy in any device of this kind (as in the cylinder used by Mr. Bell), where the upper box rests on the lower, is in the friction exerted between the two boxes where they are in contact, when motion is impending from the horizontal force applied. Where an appreciable proportion of the weight of earth and load is carried by the sides of the upper box, this friction may be quite appreciable, and should not be ignored, as is usually done.

The fact that plastic clay acts somewhat like a viscous substance, as stated by Mr. Goodrich, suggests the use of the rotating disk mentioned above to meet the difficulty. There are drawbacks in the case of the plaques, Fig. 1, the rotating disk, or the boxes, Fig. 5, which have been pointed out, and it is to be hoped that some inventor will improve upon all three.

Mr. Goodrich states, with reference to the cigar boxes (respectively 3 and 5 in. deep) filled with sand, that when the boxes "were reversed in position, the angle of tilt at which sliding took place differed". This is evidently because the weight of sand carried by the sides of the top box was different in the two cases, exactly as in the case of the Leygue experiments previously cited.

There can be no objection to the use of the term "internal friction", if it is intended to mean friction, pure and simple, as exerted

* Ketchum's "Walls and Bins", p, 323.

Mr. Cain. in the interior of a solid or earth mass. It is used in that sense by Professor Basquin in his notable paper on the "Theory of Internal Friction", and the writer has used it in that sense in his paper on "Experiments on Retaining Walls".* The close agreement found by Professor Basquin in the observed and computed values of the angle of rupture, given in the table quoted, goes far to prove that friction and pure shear (corresponding to cohesion, as previously defined) are exerted at the same time in the materials tested. To that extent, it verifies Coulomb's two laws. In these experiments, the friction is simply proportional to the normal pressure, and the pure shear (or cohesion) varies only with the area of sliding. The total shearing force exerted, sufficient to cause rupture, equals the sum of the two resistances.

Now, unfortunately, Mr. Goodrich does not seem to entertain this view of "internal friction", when earth pressure is in question, but appears to consider it as covering sufficiently both friction and cohesion. Thus he says, where the laws of variation (of cohesion and friction) are practically indentical, "there appears to be no practical reason for not using a single element to include both factors and including both in a common term." Again, he states that the separation "between sliding friction and cohesion is probably unnecessary", and, referring to "internal friction", "that a knowledge with regard to this will make possible a fairly accurate analysis of earth pressures".

The writer feels sure that if Mr. Goodrich will study Figs. 2 and 3 and read the comments thereon, he will change his views. The theories of coherent and non-coherent earth, differ very widely in their results when the cohesion factor is large.† Thus, if the surface of the earth is horizontal, the unit horizontal thrust, q, on a vertical plane in an indefinite mass of earth, subjected to no external forces but its own weight, is,

$$q = p\,\frac{1 - \sin.\,\phi}{1 + \sin.\,\phi} - 2\,k\,\frac{\cos.\,\phi}{1 + \sin.\,\phi}$$

$$= \tan.\left(45^\circ - \frac{\phi}{2}\right)\left[p \tan.\left(45^\circ - \frac{\phi}{2}\right) - 2\,k\right],$$

where p is the vertical unit pressure acting on a horizontal plane at the depth, x, considered, so that, $p = w\,x$, if w is the weight of the earth per cubic unit. The symbols, k and ϕ, have the meanings previously given. The formula does not apply when q is negative. For this upper portion of the plane, there is no pressure exerted.

This formula does not apply exactly for pressures against a rough vertical retaining wall or the vertical wall of a rough cylinder in which

* *Transactions*, Am. Soc. C. E., Vol. LXXII (1911).

† The theory of coherent earth is given in full in the writer's recent book on "Earth Pressure, Walls and Bins", from which the formula is quoted, p. 182.

earth is subjected to a vertical unit pressure, p; and neither does the Rankine formula (deduced from it by making $k = 0$) apply exactly; but, suppose earth placed in Mr. Goodrich's cylinder, with the electric buzzer, etc., and that the walls are very, very smooth, so that the friction there is very small and the pressure, p, is applied. Then the foregoing formula would apply approximately; but certainly the Rankine formula does not apply when k is not zero, and any conclusions drawn from it are unwarranted. Thus, the angle of friction cannot be found by using Rankine's formula; the formula for coherent earth alone applies. On substituting several simultaneous experimental values of p and q in this formula, the values of ϕ and k can be obtained from it by trial for the earth experimented on, but the graphical method used by Professor Basquin in the paper previously referred to,* as shown in Fig. 36 of that paper, effects the solution more readily. In this figure, the ordinate at O to the line of slip, AB, measures the cohesion, as defined in this paper. For the bank sand experimented on by Mr. Goodrich, the cohesion thus found is 500 lb. per sq. ft., the angle of friction being $\phi = 32$ degrees. It is seen, from the high value of the coefficient of cohesion, that the Rankine formula is entirely inapplicable. Mr. Cain.

If the walls of the cylinder are rough, a certain amount of arching of the material is experienced, the pressure transmitted downward is not uniform, and even the formula for coherent earth does not exactly apply.

It may be inferred from the foregoing that the writer is somewhat pessimistic as to the use of gauges in small confined spaces to reach accurate results in estimating earth pressures; still, he hopes that the Special Committee on the Bearing Value of Soils will give the method a fair trial, and will succeed in overcoming the difficulties referred to. If such tests could be supplemented with experiments on retaining walls, or frames, 6 to 10 ft. high, backed by earth at the limit of stability, the results would be more convincing.

Electrical engineers state that there are difficulties in the way of measuring earth pressure by electrical means. If such difficulties could ever be overcome, it would afford an ideal method of finding the lateral pressure at any depth in a mass of earth or against a wall.

The writer trusts that the paper and discussions have shown fully the need for extensive experimentation to determine the coefficients of friction and cohesion in every kind of earth.

His thanks are especially due to the gentlemen who have so kindly engaged in the discussion.

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* *Journal*, Western Soc. of Eng., Vol. XVII, No. 9 (November, 1912), p. 840.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SECURE SUBWAY SUPPORTS

Discussion.*

By Messrs. A. B. Lueder and W. J. R. Wilson.†

A. B. Lueder,‡ M. Am. Soc. C. E., and W. J. R. Wilson,§ Esq. (by letter).‖—The writers are much gratified by the interest and appreciation with which this paper has been received and by the discussions. They do not concur with some ideas brought out by the discussion which do not concern street supports directly. Messrs. Lueder and Wilson.

Referring to Mr. Moulton's remarks, the writers are pleased with his general approval of the paper and interested in the point of view of a mining man, although they believe that the general practice of excavating rock in a mine is not applicable to subway excavation. The paper was presented in order to illustrate a method of street support which had been used successfully and had fulfilled the conditions which it was designed to meet. The writers stated expressly that this system was not designed to take care of possible slides in the side, but so that the street supports would not be endangered by a side slide or by blasting. On Section 13 side slides were not always taken care of as it is believed they should have been, but every effort was made to eliminate them by careful supervision of the timbering and blasting. Their danger was minimized by carrying the underpinning to solid rock which had no tendency to slide, or by cantilevering the buildings off rock which was likely to slide, while depending on the tower supports in the center of the cut and the continuous beams to support the street.

* Discussion of the paper by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, Esq., continued from April, 1916, *Proceedings*.

† Authors' closure.

‡ Morristown, N. J.

§ Brooklyn, N. Y.

‖ Received by the Secretary, May 16th, 1916.

Messrs. Lueder and Wilson.

The writers think that the question of extensive side slides should be considered in the design of the permanent work. They believe that, as a prime consideration of design, the street supports should be made safe. Any system of street support which depends on the stability of rock in the sides presents a great element of danger. Transverse supports cannot be put in until excavation is made. If such supports were used, the same street loads (in such a case as on Section 13 with a transverse width of 60 ft.) would have to be carried on longer spans than if the spans were longitudinal. The supports on the unstable sides of the cut would be unsafe, but those actually used rested on the bottom in the center of the cut, and were obviously on safe rock. Where the cut was narrow, transverse supports were used, but the street was still supported on continuous longitudinal beams.

The question of side slides and the danger therefrom will always be pertinent to the subject of subway excavation in New York City, but it would seem to be good practice to take the street support design out of the realm of this danger, and the writers treated the subject in this way. The extensive side slide which would bring danger to the system, as used on Section 13, would carry away with it buildings and any transverse system possible on that section. A fairly large side slide that did occur left the street supporting system unaffected. In a wide cut, such as on Section 13, the houses are practically on the edge of the cut; they will be in danger before any system of timbering can be put in, and necessarily must be taken care of first. This was done by underpinning carried to rock which investigation showed to be sound and without seams. This method of underpinning is expensive to the city, and any method of permanent construction which would guarantee safety of all side-walls would eliminate much of the underpinning cost.

There seems to be no pertinency in Mr. Moulton's suggestions as to the use of a mining system in which the lower part of the face is kept in advance of the upper part. This would do in a tunnel, but not when there is a street overhead. It is generally agreed by experienced engineers that the open quarry method is, on the whole, the cheapest yet devised for rock cuts, and ideal subway excavation approaches that method. The writers believe that in the present system of subway building, the design of the permanent work and the shoring methods used by the contractors do not provide thoroughly against the wholesale side-slide danger referred to in the discussions. They think, however, that under the present method of bidding, the contractor is not justified in providing for such a contingency. Luckily, there has not yet been such a slide, but any engineer who has actually supervised subway construction in deep rock cuts in New York City realizes that there is a possibility that it will occur. If it does, it

Messrs. Lueder and Wilson.

will certainly mean the destruction of buildings and probably great loss of life. There would follow investigations and undoubtedly mandatory legislation compelling the supervising authorities to adopt measures for absolute safety. If such measures were framed by lawyers and politicians, it might greatly increase the cost of subway building. The contractor cannot be expected, as before stated, to adopt a fixed system of supporting the side rock, whether or not it appears to be dangerous, and no amount of supervision will stop a slide, or always foresee it; but the writers believe that the design of permanent work can be modified so that it can be made to take care of any possibility of an extensive slide, and at the same time give the contractor ample opportunity to use up-to-date methods for fast excavation and construction.

The City, of course, pays for the design and the erection of the contractor's temporary supports, and also for the final permanent construction. There seems to be no reason why a permanent design should not provide more flexibility and, to a large extent, be made to take the place of a contractor's temporary system. By being designed beforehand and bid on as part of the contract, it would provide safety to the public.

The writers admit that the contractor's loads are heavy, but they are under his control, and they certainly do not overrun red flags. Mr. Moulton's reference to excavation in pits—which is a soft ground proposition—would not apply of course to a rock section. In subway work workmen are trained in their especial trades as blasters, carpenters, etc., and it is the man who uses them who needs to be experienced. As has been stated, the writers do not consider it a safe system to allow workmen to build up a patch-work design; it should not be changeable at their whims.

Referring to Mr. Fiesel's remarks, that a comprehensive design of temporary roadway supports would add enormously to the cost of the permanent structure, does not the present form of contract pay the contractor for just such a design, and is it not the office of the Public Service Commission to see that he uses a safe design? In their experience with the Public Service Commission the writers certainly found no desire to allow a contractor to make money at the expense of public safety. The point is, though, and to that extent the writers thoroughly agree with Mr. Fiesel, that the City will have to pay a great deal more for its subway construction, if it has to pay for doing the same thing twice. That is one reason they advocate the inclusion, in the design of the permanent work, of features enabling it to fulfill for the contractor the purpose of a thoroughly safe side-wall and street-supporting system on which to bid. The writers do not intend to say that the City should design an elaborate temporary structure for the contractor, apart and separate from the design of the permanent

Messrs. Lueder and Wilson. work. They had in mind a method of construction which might have been used on Section 13, which would have provided against the danger of side slides, and have also largely answered the purpose of the street-supporting system used. This scheme, however, would have had to be part of the permanent work; the contractor could not use it separately. If, though, it had been part of the contract, it would have eliminated completely any chance of large scale disaster due to the erection of an imperfect temporary system by a contractor. The paper did not bring out very clearly the exact idea of the writers in advocating pre-designed street supports. They agree, to a certain extent, with those who discussed it, in believing that it would not be advisable to have a rigid system of temporary shoring designed by the Public Service Commission and incorporated in the contract. The public, however, should be secured by the design on which the contractor bids, as brought out by Mr. O'Brien. There is no question in the mind of any engineer experienced in subway rock work that there is a possible danger from an extensive rock slide, as referred to by Messrs. Moulton and Collier.

It is believed that the present permanent design of the subway can be modified so that it will provide against any large side slide, take the place of much of the contractor's present temporary system, and yet not add to the cost of the work to the City. With such a design, the permanent work will cost probably more for the materials used, but it will insure safety, and will make excavation and underpinning costs much less. Every contractor then would be able to figure more closely, and would have to figure on doing the work safely, because the design would provide for his doing so, and it would also provide ample leeway for ingenuity in the methods used and leave him free in his own sphere.

Mr. Collier's reference to payment for excavation beyond the neat lines for rock and concrete will interest all contractors.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A STUDY OF THE BEHAVIOR OF RAPID SAND FILTERS SUBJECTED TO THE HIGH-VELOCITY METHOD OF WASHING

Discussion.*

By Messrs. Joseph W. Ellms and John S. Gettrust.†

Joseph W. Ellms,‡ M. Am. Soc. C. E., and John S. Gettrust,§ Esq. (by letter).||—The writers are gratified that this paper has been so well discussed, and that it has brought forth so much valuable and hitherto unpublished information. Certain features of filter design not directly related to the subject matter of the paper have been brought into the discussion, and have served to heighten its interest. The close relationship between type of strainer system, method of agitation, and character of filter bed is evident from a careful reading of the experimental data submitted. Messrs. Ellms and Gettrust.

Mr. Fuller's experience with breaking strainer plates and hook-bolts, coupled with the writers' experience in the breaking of hook-bolts, would appear to indicate that, in the design of this type of strainer system, too little attention has been paid to the stresses created by the upward flow of the wash-water, and especially to those stresses developed at the instant of opening the wash-water valve.

Mr. Manahan seems to be of the opinion that the wearing away of the brass wire-cloth, by the movement of the sand particles through it, had as much to do with its deterioration as did corrosion. It is probably true that the location of the screen subjected it to consider-

* Discussion of the paper by Joseph W. Ellms, M. Am. Soc. C. E., and John S. Gettrust, Esq., continued from May, 1916, *Proceedings*.

† Author's closure.

‡ Cincinnati, Ohio.

§ Kent, Ohio.

|| Received by the Secretary, July 3d, 1916.

Messrs. Ellms and Gettrust.

able erosion, and to some strain produced by the pressure of the wash-water on those portions of the cloth where the meshes had become clogged gradually by the lodgment of fine particles of gravel in them; but it is the writers' belief that actual solution of the zinc and copper of the brass by the water passing through the screen had more to do with its destruction than the mechanical agencies. A close examination of the wire-cloth indicates a change in the character of the alloy. It is true that some corrosion of the strainer plates themselves has taken place, but, as they are of much heavier metal, and as they are not subjected to mechanical abrasion in any way, their life has not been affected materially.

The greater latitude permissible in specifications for filter sand which is to be subjected to high-velocity washing seems to be the opinion of both Mr. Stephenson and Mr. Barbour. Mr. Barbour's method of specifying sand for the Akron filter plant seems to the writers a most sensible one, and worthy of general adoption.

The valuable data submitted by Messrs. Willcomb, Barbour, Pirnie, and Armstrong are in accord with the information secured by the writers, and in general their conclusions are the same. Mr. Pirnie's conclusion: "If a filter can be constructed so that the wash-water has a uniform velocity when it passes from the gravel into the sand, there will be no tendency of the gravel and sand to mix", is sound, and sums up concisely the desirable condition to be attained. His further deduction, that all ridges are useless, the writers are inclined to believe is correct. All the dispersion effects, which would contribute toward destroying jet action from the strainers, may be obtained by directing the discharge from the strainers toward the bottom or floor of the tank, and by a sufficient depth of properly graded gravel over the strainer system. In the Wheeler bottom, as described by Mr. Barbour, we have as complete a destruction of the jet action of the wash-water, when the jet is directed upward, as has as yet been designed. How the rather broad ridges—necessitated by the construction of the inverted pyramids which hold the balls—will affect the effectiveness of washing in the section immediately above them is worth observing in filter plants using a bottom of this type.

Mr. Armstrong's experiments are of particular interest in showing the stability of the gravel layer under very high rates of washing. These rates are much higher than would ever be required in practice.

Messrs. Willcomb, Pirnie, and Johnson advance some reasons for favoring the use of an air-wash, and seem to think that it will meet certain conditions better than a high-velocity wash. Mr. Pirnie seems to think that the escaping air will break up lumps that form on the surface of the sand, which a high-velocity wash will not do. Mr. Johnson contends that some form of scrubbing action should precede

Messrs. Ellms and Gettrust.

the application of the wash-water, and that the escape of the air will do much toward preventing the formation of mud balls.

The writers' observations on agitation with compressed air are not in accord with these conclusions, and though admitting that the escape of air from a filter bed covered with a layer of water seems to produce an agitation of the sand particles, there is in reality no movement of them, or at the most only a very slight movement of the very finest particles at the surface. Any deposited colloidal coating on the sand, of course, will be broken, and will be projected in part into the overlying water; but the same effect is also produced by the rising currents of wash-water as they leave the channels between the sand grains, break through the colloidal coating on the surface, and enter the main body of the water above the sand. Scrubbing or the rubbing of the particles against each other does not take place when air is forced into the bed in the usual way prior to the application of the wash-water.

The rubbing of the sand particles against each other does take place, however, when the bed is floated by the high-velocity method of washing. In fact, the chief reason for adopting that method in the design of the Cincinnati filtration plant was, that the earlier experiments, made by one of the writers, showed that this method produced this scrubbing effect, and in a measure reproduced the action of mechanical rakes.

The formation of mud balls in filter beds, and the adhesion of the dirty sand to the sides of the tanks were common enough phenomena before the high-velocity method of washing was developed, and, consequently, their occurrence in filters cannot be charged to this particular method of washing. Mud balls in the sand, or mud banks on the sides of the tanks, or hard areas in the sand bed, are due to an insufficient quantity of wash-water, or to none at all in the spots affected. This condition may arise from the improper distribution of the wash-water, which must be due primarily to the type of strainer system used, and to the manner in which the rising wash-water is distributed after leaving the strainer openings. If forcing compressed air into the sand bed has any agitating effect at all on the coated sand grains that lay at or near the surface—as some appear to believe, but which the writers have failed to detect—it is undoubtedly true that the application of wash-water at a rate sufficient to float the sand bed effects a very much greater scrubbing action of the sand grains, and all are agreed that this is the desirable effect to be produced by any method of agitation that may be used.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

THE EFFECTS OF STRAINING STRUCTURAL STEEL AND WROUGHT IRON

Discussion.*

By Messrs. Clement E. Chase and Henry S. Prichard.†

Clement E. Chase,‡ Jun. Am. Soc. C. E. (by letter).§—Mr. Prichard's long experience with the practical manipulation and use of iron and steel, and his very thorough knowledge of the results and significance of past tests on these metals, have given him an unusual insight into their nature. It is because steel is the most important engineering material of construction and because this paper deals with the fundamentals governing its behavior in use, that it is so valuable a contribution. There is a great multiplication of tests in these days, but too often they only serve to pile up a mass of loosely connected, superficial data. Lacking a framework of sound theory to which to adjust the test data, much of the value must be wasted. Long before the entire truth is known (if it ever is) about any subject, it is possible to establish a working theory, in the light of which the results of each experimentation should be examined and the theory added to, strengthened, or modified accordingly. Mr. Chase.

The theory underlying heat action on metals is in common use in America to check and explain in this way the results of all heat treatments, but, to the writer's knowledge, this is practically the first reference in American engineering literature to the theory of strain action, or what is called the "mechanism of plastic deformation." The importance of this theory to the engineer can hardly be over-estimated. Its development was due mostly to a small group of English physicists,

* Discussion of the paper by Henry S. Prichard, M. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† Author's closure.

‡ Pittsburgh, Pa.

§ Received by the Secretary, May 9th, 1916.

Mr. Chase. Sir Alfred Ewing, Rosenhain, Humfrey, and Beilby, whose work in this line has only lately begun to be appreciated at its true worth. Their investigations led them into a hitherto unknown field—on the borderland between pure science and practical engineering—opened up by the application of the microscope to the examination of metallic structure. The first paper by Ewing and Rosenhain, announcing the discovery of the basic phenomena of the "slip bands" was published in 1900.* They then advanced the proposition that deformation under strain took place by slippage in each crystalline grain, along the cleavage planes, much as a pack of cards can be distorted without changing the shape of the individual cards. This view of the significance of the slip bands was attacked by continental scientists, and was defended in a series of able papers.† No one who reads these can help but have a feeling of great admiration for the resourcefulness, straight-thinking, and experimental skill with which these men proved their contentions and upheld their important theory. Dr. Rosenhain, who is now Superintendent of the Metallurgy Department of the National Physical Laboratory of Great Britain, last year published an excellent book in which this work is summarized.‡ Recently, American metallurgists have devoted some space in their books to the effect of strain on structure, and a new book§ by Professor Henry M. Howe, of Columbia University, devotes one of two parts to this branch of the science of metallography. In his preface, Dr. Howe says,

"The usefulness of steel really results from its resistance to deformation and its power to endure limited plastic deformation. Hence a knowledge of the mechanism of this deformation and of the way in which steel in part resists deformation and in part accommodates itself to it, may in time disclose the essence of its power of resistance and accommodation. To understand this essence is to be the better prepared to approach the problem of fitting the metal for service, not empirically alone, but also scientifically."

In the writer's opinion, this study is not one of which the metallurgists should be allowed to have any monopoly. Understanding and use of it will be of even greater value to engineers. Mr. Prichard approaches the matter from the attitude of the structural engineer. Following his thought, one is led into the subject from the familiar direction of physical tests of metal. The English metallurgists reached their conclusions largely from what they saw in the microscope. Mr. Prichard has come to the same point through searching for the significance of engineering test phenomena. It has been the writer's privilege to follow to some extent the preparation of this paper, and he regards it as worthy of record that Mr. Prichard's theory was

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* *Philosophical Transactions,* Royal Society, Vol. 353A.

† *Journal,* Iron and Steel Institute, 1904, No. 1, pp. 335–390; 1906, Vol. 2, p. 189.

‡ "An Introduction to the Study of Physical Metallurgy", Van Nostrand.

§ "The Metallography of Steel and Cast Iron".

formulated, practically in its present shape, before the work of Beilby on the mobile and amorphous states of metal was known to him. The significance of this is that it shows how thorough study of the problem from either the engineering test direction or the micro-metallurgical direction leads to the same conclusion. Mr. Chase.

Mr. Prichard states that the deformation of metals in tension and compression is in reality caused by failure to resist shear. This conclusion comes irresistibly from a study of the microscopic phenomena of slippage, which is essentially a shear action. It must also be the conclusion of any one who has watched thoughtfully the formation of the lines, referred to by Mr. Prichard, on the mill scale of tensile tests. In regard to these lines, the writer cannot agree that they usually take a direction of about 26° 34′ to a plane normal to the direction of pull. It has been his observation that this angle is more nearly 45 degrees. Tensile tests of hooping and flat steel, however, fracture usually at an angle which is about 26° to this plane. Mr. Prichard's hypothesis, on pages 77-78,* as to the manner in which the particles in the crystalline grains slip, gives a simple picture of the action. Actually, the slips in the grains occur in any direction, depending on the orientation of the grain to the shearing stress and the location of the most favorably disposed cleavage planes, and in at least as many as three directions in the same grain under severe overstrain.

Fig. 3, representing the necking down of a tensile test piece, is subject to the criticism that the actual necking of test pieces gives much more support than this figure does to the conception that the failure is by shear in ductile metals. Fig. 10 shows the tension fracture of a test bar of structural steel. The necking of the piece was parallel to the line, *S-S*, which is also parallel to the fracture. This line makes an angle of about 28° 40′ with the axis of the test piece. It will be noted that slippage occurred along the line of fracture, or the zone of fracture, to such an extent that one-half of the test is displaced $\frac{1}{16}$ in. to one side. Fractures exactly similar to this have been noted in full-sized eye-bar tests. The more symmetrical "cup" fractures of tension bars also give evidence of this failure by shear.

The writer agrees with Mr. Prichard in what he says as to the elastic limit and yield point, and believes that there would be less confusion surrounding these terms if there was more appreciation of the significance of the phenomena of plastic deformation that this paper deals with. We now have "true" elastic limit, proportional elastic limit and yield point—and others. It seems to the writer very probable that there is no "first permanent set" without a corresponding variation from proportionality—and that the two limits are, in fact, coincident. It is only the fact that delicate extensometers can detect slight permanent sets at a lower point (often due to initial strains)

* *Proceedings,* Am. Soc. C. E., for January, 1916.

Mr. Chase. than the eye can determine any regular breaking away of the stress-strain curve, that gives these two points apparently different values. The writer believes Mr. Prichard is right in saying that it is only that elastic limit which is at the beginning of the general yield that has any real significance. To indicate the method of locating the limit, the qualifying words, "by set", or, "by proportionality", might be used.

Clear light has been thrown on the long-debated question of "crystallization" and fatigue by the men to whose work Mr. Prichard refers on pages 92 and 95.* The misunderstanding, between those who believe in "crystallization" of metal in service and those who do not, is mainly one of terms. "Crystallization" would have it that metal becomes coarsely crystalline under vibration or long-continued severe

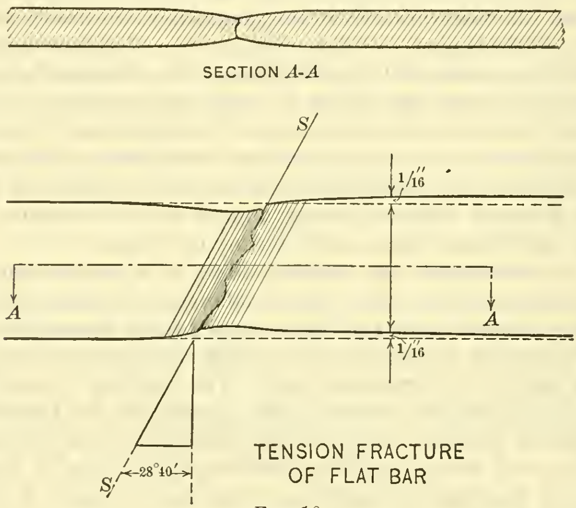

FIG. 10.

service—and points to the fracture of the metal in proof. Now, it is not true that metal becomes crystalline, for it always is crystalline—but it is true that under stresses approaching the elastic limit if repeated, or half that limit if alternated, an internal change takes place in the metal that eventually manifests itself by failure. That change is the development of internal slips into internal cracks, and results finally in a sudden snapping of the metal, with no showing of ductility, and with a fracture that satisfies the eye as crystalline. The deterioration that the layman insists on is true, if not as easily caused as he imagines—the theory as to its mechanism, that he implies in the term "crystallization", is not true. No indication has ever been found of any growth of the crystal size of steel at atmospheric temperature. However, for

* *Proceedings*, Am. Soc. C. E., for January, 1916.

those who declare offhand that the idea of crystal growth in cold steel is preposterous, there may be food for thought in the fact, which Mr. Prichard has mentioned, that in lead such crystal growth does occur under certain conditions at atmospheric temperatures. The microscope gives an explanation of the comparatively coarse size of the facets often found in a fatigue fracture. It is the progressive spread of the internal cracks in a plane through several crystalline grains while the deterioration is in progress. Mr. Chase.

HENRY S. PRICHARD,* M. AM. SOC. C. E. (by letter).†—Mr. Chase, after describing the fine achievements of the English physical metallurgists, states: Mr. Prichard.

"In the writer's opinion, this study is not one of which the metallurgists should be allowed to have any monopoly. Understanding and use of it will be of even greater value to engineers. Mr. Prichard approaches the matter from the attitude of the structural engineer. Following his thought, one is led into the subject from the familiar direction of physical tests of metal. The English metallurgists reached their conclusions largely from what they saw in the microscope. Mr. Prichard has come to the same point through searching for the significance of engineering test phenomena."

In studying the phenomenon of plastic deformation of steel and iron, not through the eyepiece of the microscope, but by applying mechanical principles to the ordinary physical tests, the writer conceived of the flow by which the deformation is accomplished as consisting of the sliding relatively to each other of perfectly elastic solid particles separated by thin highly viscous mobile or liquid films. The investigations of the English physical metallurgists, as described by Messrs. Chase and Irwin, have led to precisely this conclusion. Under refined and ingenious methods of microscopical research with great magnifications the little masses or grains, as they are called, which are disclosed by ordinary microscopical examination, are shown to be compound, and have been resolved into numerous crystalline elements which are in themselves little crystals, and constitute the fundamental grains of the solid portions of the metal, which slide relatively to each other during plastic deformation.

As to the theory formulated by Mr. Irwin, and attributed by him to the writer, to the effect that these aforementioned compound grains remain perfectly elastic during plastic deformation, the writer had not the slightest intention of promulgating any such idea; on the contrary, it may be noted, incidentally, that, in referring, on page 77,‡ to what is seen under the microscope, he did not state that the slips between the sliding particles appeared as sharply defined lines

* Pittsburgh, Pa.

† Received by the Secretary June 12th, 1916.

‡ *Proceedings*, Am. Soc. C. E., for January, 1916.

Mr. Prichard.

between the grains, but as sharply defined lines on the polished surface of each grain. The writer, however, was dealing primarily with the principles involved and not with the precise inner structure of the metal. It was not necessary, and he did not choose, to complicate the application of the principles by introducing details of structure; but he hoped that the details of structure would be discussed, and he is pleased that this phase of the subject has since been so ably handled by Mr. Irwin.

The current theory of plastic deformation included in the paper is useful in explaining the effects of over-straining iron and steel, and is destined to become of service in guiding the course of future experimentation.

The theory, as Mr. Chase explains, is not very old, and has only recently been presented to American engineers. That there should be some criticism and opposition is natural.

Phases of the theory have been investigated independently from different standpoints. Writers on theoretical mechanics have proposed three theories of the breakdown of the elastic resistance of an isotropic solid, as follows:

First.—That the elastic limit is reached at a certain intensity of direct stress;

Second.—That the elastic limit is reached at a certain intensity of linear strain;

Third.—That the elastic limit is reached at a certain intensity of shear. This was proposed by Mr. J. J. Guest,* and is the latest of the three theories.

Mr. Moore states that the paper quotes Mr. Hancock's tests as a proof of the maximum shear theory, and questions whether they are a confirmation. The word "proof" is a little too strong. The paper, in referring to plastic materials, made the statement:

"That shear is the critical consideration is supported by experiments and analysis of J. J. Guest, Professor E. L. Hancock, and others."

The comparative results of Hancock's tests† (of steel) are as given in Table 8.

After considering the results of many tests, the writer reached the conclusion, held by most authorities, that brittle or comminuible materials, under simple compressive loads, fail by shearing on planes at certain definite angles with the direction of the load; and, in comparing the theoretical and the actual planes on which slipping oc-

* *Phil. Mag.*, July, 1900.

† *Proceedings*, Am. Soc. for Testing Materials, Vol. VI, 1906, p. 305; and Vol. VII, 1907, p. 271.

curred, he remembered that slipping is resisted by friction (a feature on which Mr. Jonson lays stress, page 533*), and followed Navier's analysis.† Mr. Prichard.

TABLE 8.—PERCENTAGES WHICH THE MAXIMUM STRESS, STRAIN, AND SHEAR FROM TENSION OR COMPRESSION COMBINED WITH TORSION IN VARIOUS PROPORTIONS, ARE OF THE MAXIMUM STRESS, STRAIN, AND SHEAR FROM TENSION OR COMPRESSION ALONE.

Computed from Hancock's observations at the elastic limits, on the assumptions that these limits were well defined, that the material for each set of tests was uniform, perfectly elastic, isotropic, and free from initial stresses, and that Poisson's ratio (which affects strain only) was one-third.

Number of tests averaged.	Proportions of average tension or compression and average shear from torsion.	Maximum stress. Percentage.	Maximum strain. Percentage.	Maximum shear. Percentage.
	Criterion by each theory for all cases.....	100	100	100
Tubes, 1 in. outer diameter, $\frac{3}{64}$ to $\frac{1}{4}$ in. thickness (t).				
3	(Shear ÷ Tension or Compression) = 0.120	97.9	98.8	99.2
8	do = 0.280	82.3	84.0	100.8
4	do = 0.610	78.8	84.7	96.4
5	do = 1.017	71.3	81.2	99.8
(t = ¼ in.) 1	do = 1.500	83.3	97.7	126.6
5	Shear only (from Torsion)..................	55.7	74.3	111.4
Solid Sections.				
4	(Shear ÷ Tension or Compression) = 0.220	93.8	96.2	99.2
3	do = 0.397	97.8	101.5	107.6
6	do = 0.613	100.5	108.6	124.8
2	do = 0.942	100.8	115.5	129.6
3	do = 1.880	120.1	145.7	196.8
3	Shear only (from Torsion)..................	74.3	99.0	148.6

The writer reached the conclusion that plastic materials under simple tension or compression slide on slippage or gliding planes, from a study of the phenomena displayed in tests and, later, from Sir J. Alfred Ewing's account of his microscopical examinations. The conclusion that it was the shearing components of the simple tension or compression, acting on planes of maximum shear and uninfluenced by the component normal to these planes, was drawn from the fact that the elastic limit is the same in both tension and compression. Hancock's experiments on tubes support the theory that shear is critical. His experiments on solid sections seem to

* *Proceedings*, Am. Soc. C. E., for April, 1916.

† As given in Johnson's "Materials of Construction", p. 24.

Mr. Prichard. favor the theory that stress is critical, but, in the writer's judgment, the computed results are much in error and untrustworthy. For solid sections, in such cases, the elastic limit is not well defined, and this and other departures from the assumptions tend to indicate stresses and shears much higher than the actual.

The writer's conception of shear is by no means "peculiar", as Mr. Jonson suggests. On the contrary, the conception of shear, as given on page 76,* is so orthodox that it can be found in any textbook on mechanics.

It may be well at this point to define shear:

"An action or force which causes or tends to cause two contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact" (Webster).

Before the elastic limit is reached, shear only tends to cause contiguous parts of a body to slide relatively to each other.

According to Mr. Jonson, flow begins when the shear reaches the elastic limit, and flow takes place "only when the shear exceeds the elastic limit." This is in exact accord with the paper (page 80).*

The important differences between Mr. Jonson and the writer are in regard to what takes place beyond the elastic limit, and are two in number:

First, the writer contends that, beyond the elastic limit, the shear causes "contiguous parts of a body to slide relatively to each other in a direction parallel to their plane of contact," and that flow is the combination of a multitude of such slidings of numerous small parts accompanied by such rotations of the parts as may be necessary to continuity and alignment; but Mr. Jonson contends that the "use of the words 'sliding' and 'slipping' in connection with flow seems to be unfortunate, because flow is something entirely different from slipping. Flow consists of an indefinitely extended, angular deformation".

Second, the writer contends that part of the work done by the load after the elastic limit is reached consists in liquefying films of metal between the sliding surfaces, or, as Beilby puts it, conferring on them by purely mechanical movement the "mobility of the liquid state" (pages 80 and 100);* Mr. Jonson, on the other hand, states:

"The author seems to conceive of the flow which takes place in ductile metals when stressed beyond the yield point as if it were due to a change in the metal from the solid to the liquid state. The energy required to bring about this change of state he seems to regard as a part of the work done by the load. This, however, is not in accordance with the facts. All the work done by the load previous to the beginning of flow is stored in the test piece as elastic energy."

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*_Proceedings_, Am. Soc. C. E., for January, 1916.

Mr. Chase, after referring to the fact that deformation of plastic metals in tension and compression is caused by failure to resist shear, states: Mr. Prichard.

"This conclusion comes irresistibly from a study of the microscopic phenomena of slippage, which is essentially a shear action. It must also be the conclusion of any one who has watched thoughtfully the formation of lines, referred to by Mr. Prichard, on the mill scale of tensile tests."

(Incidentally, it may be stated that Mr. Chase considers that for these lines the angle of 26° 34′ to a plane normal to the direction of pull is too small. This angle was given in the paper as a rough approximation obtained by averaging the tangents of 0° and 45 degrees. A slippage plane, at an angle of 45° with a plane normal to the direction of the force, may make any angle between 0° and 45° with the surface of the test piece. The writer, since the paper was presented, has computed the average of the angles cut out by all possible intersections as nearly 32½ degrees.)

The facts discovered by the "small group of English physicists", to whom the development of the theory of the "Mechanism of plastic deformation" is mainly due, are so pertinent that it may be well to let these physicists tell the story. Mr. Beilby's account of what followed "The discovery that layers of a solid many hundreds of molecules in thickness can have a mobility of the liquid state conferred on them by purely mechanical movement" is quoted in the paper (page 100).*

Sir J. Alfred Ewing's account of the slips which take place within the crystalline grains of metal after the elastic limit is passed, is taken from a copy of the 1912 May Lecture before the Institute of Metals on "The Inner Structure of Simple Metals", with which the author recently favored the writer. The photo-micrographs referred to are reproduced by the authority of the Institute of Metals and Sir J. Alfred Ewing.

"My intention to-night is first to remind you briefly of some of the things that the microscope has taught us regarding simple metals, and then to go on to some more or less speculative considerations based on that knowledge. I propose to confine myself definitely to simple metals—that is, metals which behave as pure metals behave, leaving untouched the large and complicated subject of the alloys. Alloys present complexities that would only distract attention from the particular points which I wish to bring before you. Without those complexities we shall find the matter difficult enough.

"Some apology is due to the experts in the audience for presenting facts with which they are already familiar, but probably the audience includes some who are not experts, and in any case it is convenient to recapitulate a little of our positive knowledge before entering the region of speculation.

* *Proceedings*, Am. Soc. C. E., for January, 1916.

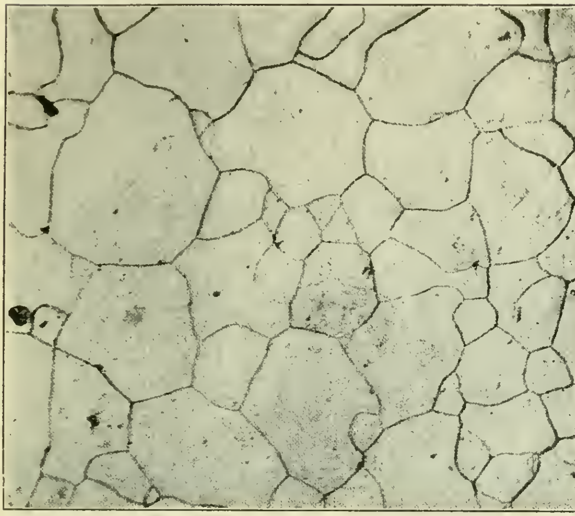
Mr. Prichard.

"Generally speaking, when we wish to apply the microscope to the examination of metallic structure, we begin by polishing the surface of the metal so as to remove those inequalities which would embarrass the use of the microscope, especially at high powers. As Dr. Beilby showed in the admirable May Lecture he gave last year, the process of polishing itself affects the constitution. It makes the metal on and near the surface entirely different in character from the metal within. It produces, according to his view—which, I think, is now generally accepted—an amorphous layer in contradistinction to the crystalline structure which, as we shall presently see, is revealed when that amorphous layer is removed. Consequently, what we have first to do after polishing is to remove the superficial layer before we can really see the normal characteristics of the structure, and the usual manner in which that layer is removed is by a light chemical attack, a slight etching with an acid or some other substance. Occasionally, we may resort to other means of removing the layer. An interesting method which is sometimes available is to heat the metal sufficiently to make the surface layer sublime away.

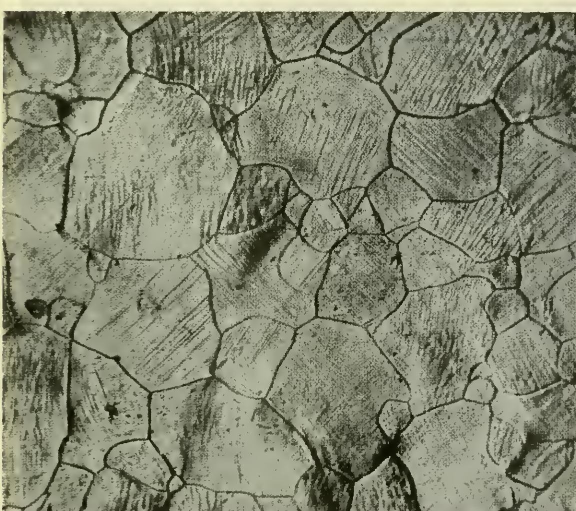
"When we lightly etch the surface of a metal, what do we see? In general we see an appearance such as is illustrated in Fig. 1, Plate I. This is a photomicrograph taken by Dr. Rosenhain of part of the surface of a bar of Swedish iron, magnified 150 diameters. A very similar appearance is presented by other metals. The surface is seen to be composed of a large number of separate grains, irregular both in size and shape, and also irregular as regards the character of the boundaries. Sometimes these are straight and sometimes curved. The shapes of the grains are as irregular as the counties in a map of England; their boundaries depend, like those of the counties, on historical conditions, as we shall see by and by.

"Suppose now that we carry the etching a little further (Fig 2, Plate II). We discover that the grains can be distinguished not merely by these irregular boundaries. A difference of texture begins to manifest itself between one grain and another; some grains are very bright, some are more or less dark, and some are very dark. If instead of illuminating the surface directly from above, as is the case in Fig. 2, we throw the light from one side, we discover that the same grain which appears bright under one condition of illumination becomes dark under another. Compare Fig. 3, Plate II, with Fig. 2.

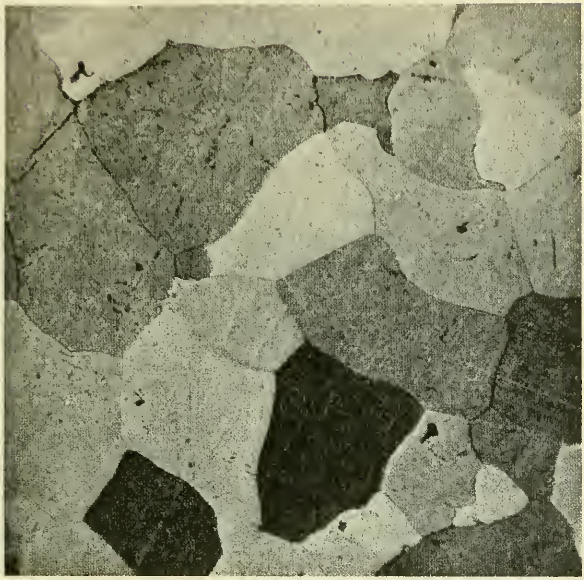
"These are two photographs, for which I am indebted to Dr. Rosenhain, showing the same part of the surface of one metal under two different conditions of illumination. In Fig. 2 the light comes directly from above; it strikes the surface perpendicularly, and is reflected up into the microscope. In Fig. 3 the same grains are illuminated by light coming from one side. It will be observed that there is no difficulty in identifying the same grains in both; and that grains which are very bright under the first illumination become dark under the other. If we move the source of light to another side, or turn the specimen round, so as to alter the direction from which the light falls upon it, we find the grains vary in brightness in the most remarkable manner, sometimes flashing out brilliantly and sometimes becoming almost entirely dark. This is true of all metals. These



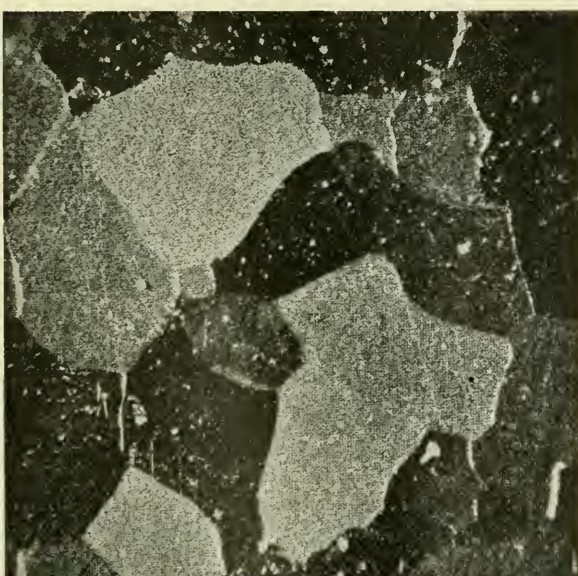
"FIG. 1, PLATE I.—BAR SWEDISH IRON AS ROLLED. MAGNIFIED 150 DIAMETERS."



"FIG. 10, PLATE I.—SAME SURFACE AS FIG. 1 AFTER STRAINING IN TENSION, SHOWING SLIP BANDS."



"FIG. 2, PLATE II.—NEARLY PURE IRON ANNEALED IN HYDROGEN AND DEEPLY ETCHED. MAGNIFIED 100 DIAMETERS. VERTICAL ILLUMINATION. (ROSENHAIN.)"



"FIG. 3, PLATE II.—SAME SURFACE AS FIG. 2, BUT WITH OBLIQUE ILLUMINATION."

photographs are of iron, but we find gold, silver, copper, lead, and so forth, exhibiting precisely the same general characteristics. Mr. Prichard.

"Examination of the etched surface under a high power shows that this difference of texture is really due to a multitude of little facets or tiny plane surfaces in each grain which are causing the general surface of the grain to reflect light in a particular manner. They are acting like a multitude of little mirrors all facing one way. These facets are parallel in any one grain, but have different inclinations in the different grains.

"In Fig. 4, Plate III, we have a photograph of a grain of iron, not very deeply etched. A part of a single grain occupies nearly all the photograph under a power of 800 diameters. You observe that over the grain, here and there, are a number of pits which are clearly geometrical in form; they happen to be nearly square in this particular case. In some places a number of pits have run together forming a black irregular patch, but in other places you can see the individual pits quite clearly. These pits are formed in the process of etching.

"Under more favourable conditions, with deeper etching, the whole surface becomes covered with such pits. Fig. 5, Plate III, is a photograph published a good many years ago by Dr. Stead, which shows very clearly what it is that gives rise to what I have called the texture of the grain. In the former example you had only isolated pits, but in this one the appearance is such as would be presented if we were to take a great mass of brick work and pick out the superficial bricks all over it, so as to reveal the character of the structure as built up of brickbats. That, in effect, is what happens in the etching of a metal.

"I do not know any example which gives a clearer indication than this does of what causes the difference of texture in the surface of these grains, nor one that indicates more plainly the real nature of their structure, as developed by etching. One can see unmistakably how the surface of the grain consists of a multitude of geometrically similar pieces, parallel to one another, so that their corresponding facets are all oriented one way. They are oriented in different ways as we pass from grain to grain, but in any one grain they face one way, and in consequence of that the light which falls on the grain is reflected in a perfectly uniform manner over the whole expanse of that grain, although it is reflected in a very different manner from the surface of any other grain. Over each grain the brightness is uniform, because the little surfaces are acting equally as regards the reflection of light.

"From this it is an easy step to infer that throughout the whole volume of any one grain there is an assemblage of pieces, which we may think of as the "brickbats" or structural units that build up the grain, all facing one way in the one grain, but facing different ways in different grains. Fig. 6, Plate IV, is another example, a piece of etched tin-plate, exhibiting the same characteristics. It shows a portion of two grains of the thin layer of tin with the boundary between them, and the difference of brightness is very marked. They are both exposed to the same light, but they reflect different amounts into the microscope. The reason is that the little facets on one are much more favourably directed for the purpose of reflecting the light back to the microscope than are the facets on the other.

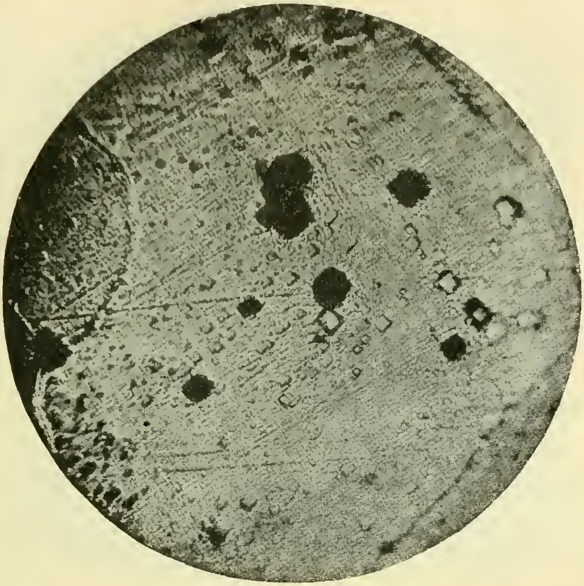
Mr. Prichard. "One might multiply illustrations all pointing to the same fact, namely, that the etching has revealed a definite geometrical structure within the grain by removing, as it were, a few of the superficial brickbats, leaving cavities and protuberances of a geometrical form. The conclusion is simply this, that every one of these grains is in reality a crystal. Notwithstanding the irregularity of the boundary it has the true property of a crystal, the uniformity of internal structure which is the characteristic of a crystal. It is, to use Kelvin's phrase, a 'homogeneous assemblage' of structural units which is put together with greater regularity than any structure built up of definitely formed brickbats." * * *

"A very important point about metallic structure is that we find true crystal grains not only in metals in the cast state but also in metals in other states, metals which have been wrought, which have been shaped by working even in the cold condition, and also in metals that have been worked in the cold condition and have afterwards been annealed by bringing them to such a temperature that a rearrangement of the grains has taken place. Whether we deal with them in the cold condition or in the annealed condition, we still find the same general characteristics, still the same granular structure, and still the same plain evidence that each grain is in reality a crystal.

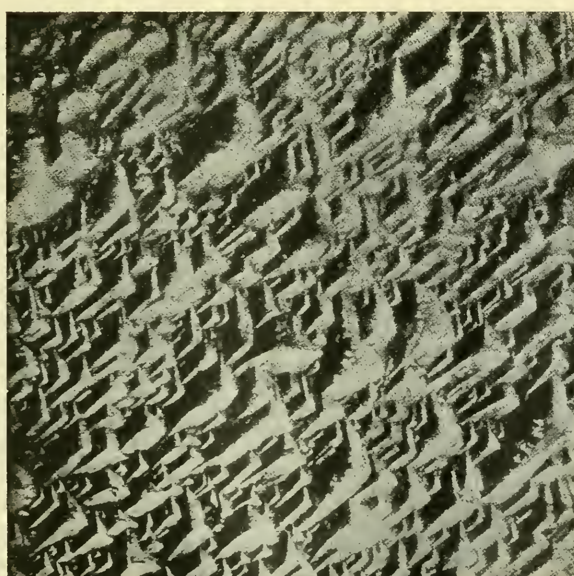
"Take, for instance, a bar that has been shaped by being passed through a rolling-mill in the cold state. One of the photographs already shown (Fig. 4, Plate III) is part of the transverse section of a cold-rolled iron bar, rolled down from a comparatively large diameter, so that the individual grains within the bar have suffered tremendous distortion in the process of rolling. The greater part of the field is covered by a single crystal. Over its whole surface there are geometrical pits. When it was examined very carefully in the research by Dr. Rosenhain and myself we found that these pits were parallel all over the crystal notwithstanding the tremendous distortion it had undergone. It was clear, therefore, that the regular parallel grouping of the structural units or brickbats had in some way or other been preserved during the process of severe straining.

"The point is further illustrated if you examine in the microscope a specimen of metal that has been broken in a testing machine. Take a fairly plastic metal, such as iron or mild steel, which stretches a good deal before it breaks. If you polish and etch the side of the bar near the fracture, where a considerable amount of extension has taken place, you will find that the metal there consists of grains similar to those you have already seen, but with this difference, that these grains are all elongated in the direction of the stretching. Their shapes may be still very irregular, but there is clearly a predominating greater length in the direction along the bar, as compared with the transverse direction. The stretching the specimen underwent before it broke has elongated each grain, but its granular character persists.

"The crystalline constitution of the grains, then, survives severe straining. How does it do so? That is a question Dr. Rosenhain and I set ourselves to answer. We tested specimens of metal by straining them actually under the lens of the microscope and observing what happened during the process. The specimen was a thin strip of sheet metal, which was strained in such a manner that the same crystals

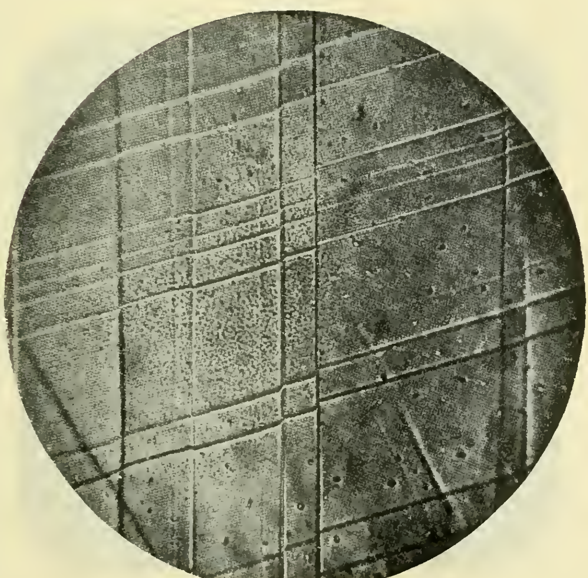


"FIG. 4, PLATE III.—IRON, SHOWING PITS PRODUCED BY ETCHING. MAGNIFIED 800 DIAMETERS."



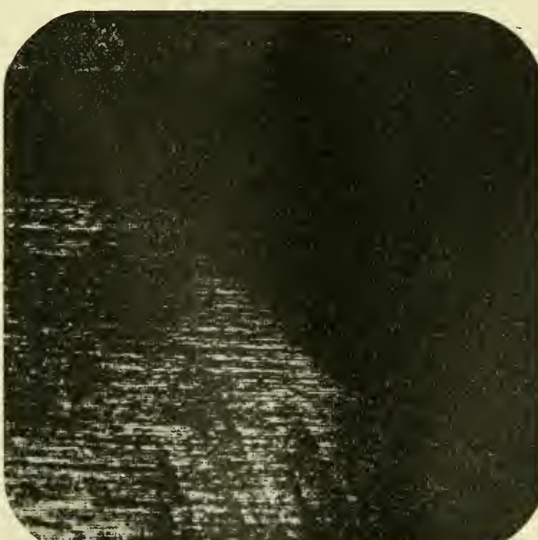
"FIG. 5, PLATE III.—SILICON STEEL. MAGNIFIED 130 DIAMETERS. (J. E. STEAD.)"

"FIG. 6, PLATE IV.—TIN PLATE, SHOWING BOUNDARY BETWEEN TWO GRAINS OF THE TIN. MAGNIFIED 100 DIAMETERS."



"FIG. 15, PLATE VI.—SLIP BANDS IN STRAINED LEAD. MAGNIFIED 1 000 DIAMETERS."

"FIG. 13, PLATE VII.—LEAD AFTER STRAINING, WITH SLIP BANDS SHOWN BY OBLIQUE LIGHTING. MAGNIFIED 100 DIAMETERS."



"FIG. 14, PLATE VII.—SAME SURFACE AS FIG. 13, BUT WITH DIRECTION OF LIGHTING ALTERED TO SHOW SLIP BANDS ON A NEIGHBOURING GRAIN."

were kept in view the whole time. In Fig. 1, Plate I, we had a specimen of iron lightly etched. This was subsequently strained by tension, but the photograph of Fig. 1 was taken before the straining began. In Fig. 10, Plate I, we have identically the same grains after a slight amount of straining—enough to carry it beyond the elastic limit, but not much beyond. If we compare those two accurately by applying compasses and measuring the lengths of the grains, it will be found that in Fig. 10 each grain has become a little stretched in one direction and a little shortened in the transverse direction. But that is not the main difference. The main difference produced by the straining is that over the surface of each grain a number of curious black lines have appeared, almost like the crevasses of a glacier, lines which are substantially straight and substantially parallel. It is in virtue of these lines that the plastic strain of the crystal grain has happened. These lines mean not that crevasses are formed, for there is no rupture of continuity, but that there has been shearing at a corresponding number of internal surfaces, that the crystal grain has behaved as a pack of cards behaves when you try to make it alter its form. The pack of cards becomes strained by the slipping of one card on the other, of each layer on its neighbor. In precisely the same way the crystals of metal become strained by the slipping of the little brickbats of one layer on those of the adjacent layer within each grain. The result is that on the polished and etched surface little steps are formed by the slipping, and it is these little steps that constitute the black lines you are now looking at. They are narrow bands rather than lines; Dr. Rosenhain and I, when first we discovered them, called them 'slip bands'." * * * Mr. Prichard.

"Clear proof that the slip lines are really little steps was furnished by testing the effect of oblique illumination. It will be obvious that, if the theory is correct, it should be possible, by throwing the light from the side, to get the little step which was dark in the first instance to shine up brightly. We have only to choose an appropriate direction from which the light should come in order that the step may reflect it up into the microscope. That has been done in this slide. Here are illustrations of what Dr. Rosenhain and I found when we made that experiment. In Fig. 13, Plate VII, we have several grains of a strained specimen of lead illuminated by light falling very obliquely from one side. The light is so placed that some of the slip lines or slip bands are bright, through reflection from the little steps up into the microscope. The light is falling on all the grains alike, but only one is visible, because none of the slip lines on the others are favourably situated for reflection into the microscope. Now we shift round the direction of the illumination (Fig. 14, Plate VII): another crystal has its slip lines brilliantly illuminated, and at the same time the one that had its lines illuminated before has now become dark.

"Fig. 15, Plate VI, is a photograph of the system of slip lines on a small part of a single lead crystal under a magnification of 1 000 diameters. You can see that the slips have produced small differences of level, and it is apparent that they have taken place successively in the different planes, so as to result in a compound system of steps.

"Dr. Rosenhain gave subsequently a further demonstration by obtaining a transverse section of the steps formed by slipping. To do

Mr. Prichard. this he strained a piece of iron to form the lines, and then deposited a thick layer of copper upon it by an electrolytic process; finally he cut a transverse section through both the iron and the copper covering, and polished that for microscopic examination. Under a high power it was seen that the surface between the two metals had upon it a number of little definite parallel steps, which corresponded to the slip lines produced by straining the iron.

"We conclude, then, that the plastic yielding of metals under strain is due to slips occurring on the gliding planes of the crystal grains. This notion gives a key to plasticity in metals. It is not going too far to say that any amount of distortion can be accounted for by slips of this kind without requiring the continuity of the crystalline structure to be interrupted."

The continuation of this story of the "Mechanism of plastic deformation" is by Dr. Rosenhain:

"If we realise the true nature of this phenomenon of deformation by slip, we see at once that it throws a flood of light on the behaviour of metals under stresses sufficient to bring about plastic strain. If such plastic strain occurs solely by slip, then the truly crystalline nature of the metal should remain unaltered by the straining process. We have already seen that strained, *i. e.*, elongated crystals, still exhibit the essential characteristics of crystals, so that, broadly speaking, this generalisation is correct. But there are a whole series of other phenomena connected with the process of plastic strain which would be extremely difficult to explain satisfactorily on any theory which required the structure of metal to remain perfectly crystalline, even when very severely strained. The circumstance that a metal is hardened by strain, in the sense of having a much higher yield-point and limit of elasticity, and even a higher breaking stress, is one of these facts. These circumstances have led the author to adopt a view put forward in the first place by Beilby [p. 100], to the effect that while plastic deformation—and although we have merely discussed its occurrence in connection with tensile strain, its nature and mechanism is the same whatever the system of forces which have brought it about—takes place by slip on the gliding planes of metallic crystals, yet that the act of slipping is accompanied by something further. Just as the rubbing action of polishing produces on metal surfaces a thin layer of altered, amorphous material, so we may well expect that the sliding over one another of adjacent slip surfaces will produce a local disturbance of molecular arrangement. If the slip is slight, then it probably happens that this derangement is also slight and temporary and that the disturbed molecules are still able to rearrange themselves pretty much in their original system. In such a case the crystalline orientation is not at all disturbed. If, on the other hand, the slip has been more pronounced, the resulting local disturbance will also be more far-reaching, a greater number of molecules will be disturbed, and they will no longer be able to re-arrange themselves in the old crystalline system. A more or less thin layer of amorphous metal will thus be formed on each surface of slip. At first—for a short time—these layers will probably possess a certain degree of mobility, like the surface film which adjusts itself under surface

Mr. Prichard.

tension. During this period these layers would act as a sort of lubricant, facilitating further slip on the same gliding planes. After a time, however, when the disturbed molecules have had time to 'set' in the amorphous condition, we should have on each plane where slip has taken place a layer of hard, non-plastic, amorphous metal. These would effectually prevent further slip on that particular set of gliding planes, and the crystals would be limited, in accommodating themselves to further plastic strains, to slip on other surfaces which had not been 'used' in the previous straining. But all the surfaces of *easiest* slip will have been used at the first straining, so that to effect plastic deformation the second time more force would be required. Not only this, but the hard and brittle amorphous films on the surfaces of previous slip would also act as a stiffening skeleton for the whole crystal and thus offer additional resistance to the commencement of fresh slip." * * *

"If we regard cohesion within the body of a crystal as being due to the attractions between layers of adjacent molecules, we can readily understand the continuity of such cohesion acting throughout the entire mass of any one crystal. The forces which are at work in producing cohesion between adjacent crystals must, however, be of a somewhat different character, for it is obvious that the regular arrangement of molecules in oriented layers cannot be carried on through a crystal boundary, while it appears that the actual cohesion between adjacent crystals is stronger than that between different layers of the same crystal." * * *

"In addition to changing their own shapes, the crystals must move relatively to one another. The strength of the crystal boundaries is found to resist such movement, and the slip-bands are found to be arranged in such a way as to minimise the amount of displacement occurring at the actual boundaries. In other words, the metal takes up the new shape imposed on it, as far as possible, by means of slip within the crystals and with as little disturbance as possible of the inter-crystalline boundaries. That there is some definite movement at the boundaries becomes evident if a polished specimen is strained without being previously etched; the effect of the strain at once causes the crystal boundaries to become visible on the surface."*

Structural steel is a mixture in which more or less connected hard grains of an alloy termed pearlite are embedded in a softer matrix composed of grains of iron. The grains of pearlite consist of alternate thin layers of iron (Fe) and cementite (Fe_3C) in the proportion of six parts of iron to one part of cementite. If a specimen of such an alloy is

"provided with a polished surface and is then plastically strained, it will be found that the effect on its surface appearance is almost identical with that obtained by etching—the laminated structure is very clearly revealed. Close examination has shown that what really happens is that slip occurs along, or very close to, the boundaries of the

* "An Introduction to the Study of Physical Metallurgy", by Walter Rosenhain, Superintendent, Metallurgy Department, National Physical Laboratory, pp. 245–247, 257 and 258.

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lamellæ of the two constituents present. When it is borne in mind that these lamellæ are formed by the process of crystallisation, it will be seen that their surfaces must lie on or near to some of the principal crystallographic planes, so that it is not really surprising that slip should occur on these surfaces."*

Grains of iron, as shown by photo-micrographs, are irregular as to size and shape, somewhat as in Fig. 11, except for the grain, *A-B-F-G,* which is drawn of conventional shape for simplicity of illustration. The slipping of the layers of the grain upward and to the right as a result of over-straining is shown in Fig. 12, which is drawn for the grain, *A-B-F-G,* enlarged. A second slippage upward and to the left will make offsets in the first slippage planes, as in Fig. 13. If the layers simply slipped, the grain, as a whole,

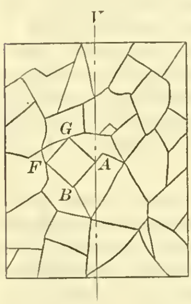

FIG. 11

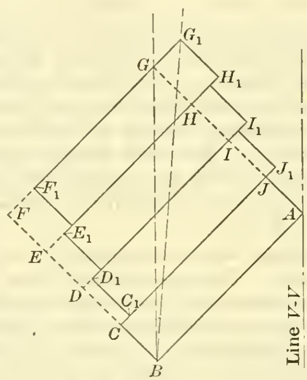

FIG. 12.

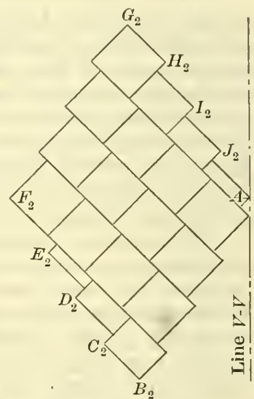

FIG. 13.

would tip to the right on the first slippage and crowd the neighboring grain adjacent to the line, *A-G,* and would tip back again on the second slippage. It is Professor Howe's opinion that the layers simply slip and project into the adjoining grains. He has discussed the matter at some length,† and concludes that the phenomena observed are those which would naturally follow in case there were no such rotation. It seems to the writer, however, that the geometrical necessities of the case require some slight rotation of the layers with each slip. The aggregate angle of rotation might not be great, however, as the rotations from slips in opposite directions tend to balance.

Professor Howe gives a valuable analysis of the effect of the rapid hardening of mobile metal during a test. It is pointed out in

* *Ibid,* p. 261.

† "Metallography of Steel and Cast Iron."

the paper that such action may take place (page 90*). The writer does not consider that all the metal made mobile or viscous during a test will entirely solidify before the test is completed. Some portion may remain viscous for a while during a rest after being over-strained (pages 90-91*), and for a long while under repeated stresses. Professor Howe's suggestion, that a very important degree of true fatigue may occur, even before sub-microscopic tears form, seems to be in line with this thought and very reasonable. Mr. Prichard.

That there is a temporary fatigue is shown by the behavior of iron and steel for a period after being over-strained. One manifestation is greater deformation under repeated stresses within the primitive elastic limit, as illustrated in Table 9, and under alternating stresses, as shown by a paper recently read before the Royal Society.†

The presence of some viscous metal on the planes of slippage and beneath the polished surface of the test piece would facilitate etching; and its subsequent solidification during a rest or gentle heating would make the test piece more difficult to etch, and thus explain "why after a heating so gentle as to intensify the hardness caused by deformation no traces of the amorphous metal along the slip planes can be detected."

"The explanation of the process of failure by 'fatigue', *i. e.*, under the repeated alternations of a stress which would not cause fracture if steadily applied, is also furnished by the conceptions described above as to the behaviour of a crystalline aggregate under strain. A stress which is to cause ultimate failure after repeated alternations must be large enough to produce a small amount of local yielding in the metal. This may be so small in amount as to be unobservable, even with a delicate extensometer, and in that case the stress would be regarded as lying within the apparent or 'primitive' elastic limit, but the microscopic examination of polished test-pieces under load has shown that the formation of slip-bands in isolated crystals here and there in the metal may and does occur for stresses of this kind. Some crystals, by their shape and the orientation of their gliding planes are unfavourably situated to resist the particular system of stresses which has been applied, and a slight local slip takes place.

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* *Proceedings*, Am. Soc. C. E., for January, 1916.

† The following is a transcript of a printed abstract, from the paper, furnished to the writer by Professor W. C. Unwin:

"W. Mason. On Speed Effect and Recovery in Slow-Speed Alternating Stress Tests. Communicated by Professor B. Hopkinson, F. R. S."

Repeated cycles of equal direct and reverse torque have been applied to mild steel specimens of tubular form, and systematic measurements made of the range of the corresponding torsional strains. The speed of application of the cycles was varied between 2 and 200 per minute. After a considerable number of cycles at 2 per minute, the range of non-elastic strain was reduced about 50% on change of speed to 200 per minute, the range of torque being unaltered.

Similarly, if a specimen had endured a considerable number of cycles at 200 per minute, the range of non-elastic strain was immediately increased by 50 to 75% at change of speed to 2 per minute. If the latter speed was maintained, the augumented range of strain decreased, quickly at first, then more and more slowly. This recovery is compared with the reduction of range of strain due to a period of rest. The author attempts to account for these variations of strain on the hypothesis of alternate production and hardening of "mobile material in the steel."

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TABLE 9.—PROGRESSIVE INCREASE IN STRETCHING EFFECT OF SUCCESSIVE INCREASES IN LOAD (PULL) FROM 5 000 TO 40 000 LB. PER SQ. IN. ON A SPECIMEN, FROM A STEEL MORTAR HOOP, WHICH WAS SUCCESSIVELY STRAINED BEYOND ITS PRIMITIVE ELASTIC LIMIT OF 45 000 LB. PER SQ. IN. BEFORE THE LOAD WAS REDUCED AND AGAIN INCREASED.

Length of Specimen, 52½ in.; Gauged Length, 30 in. Compiled from Test No. 110, Watertown Arsenal Report, 1884, pp. 345-347.

Increase in Load (Pull), per Square Inch.		First Loading.		Second loading. Elongation per inch, in inches.	Third loading. Elongation per inch, in inches.	Fourth loading. Elongation per inch, in inches.	Rested under initial load of 1 000 lb. per sq. in., 15 hours.	Fifth loading. Elongation per inch, in inches.	Sixth loading. Elongation per inch, in inches.
From:	To:	Permanent set, in inches.	Elongation per inch, in inches.						
5 000	10 000	0.0	0.000194	0.000193	0.000217	0.000210		0.000210	0.000200
10 000	15 000	0.0	0.000160	0.000177	0.000193	0.000200		0.000190	0.000220
15 000	20 000	0.0	0.000160	0.000176	0.000190	0.000197		0.000207	0.000196
20 000	25 000	0.0	0.000170	0.000187	0.000190	0.000203		0.000197	0.000194
25 000	30 000	0.0	0.000160	0.000187	0.000200	0.000200		0.000203	0.000226
30 000	35 000	0.0	0.000163	0.000186	0.000217	0.000210		0.000207	0.000204
35 000	40 000	0.0	0.000173	0.000200	0.000203	0.000224		0.000206	0.000223
Total of the above 5 000	40 000	0.0	0.001180	0.001306	0.001410	0.001444		0.001420	0.001463
40 000	45 000	0.000017	0.000177	0.000227	0.000240	0.000220		0.000227	0.000217
45 000	49 000	....	0.001260	....	....	....		....	....
45 000	50 000	....	....	0.000383	0.000250	0.000243		0.000230	0.000233
50 000	55 000	....	....	0.005194	....	....		....	0.000250
50 000	56 000	....	....	....	0.000720	....		....	....
56 000	60 000	....	....	....	0.004604	....		....	....
55 000	60 000	....	....	....	....	....		....	0.000253
50 000	62 000	....	....	....	....	....		0.002643	....
60 000	65 000	....	....	....	....	....		....	0.000310
62 000	70 000	....	....	....	....	....		0.011560	....
65 000	72 000	....	....	....	....	....		....	0.003407
72 000	86 000	....	....	....	....	....		....	0.077300

Ultimate strength on sixth loading, 87 170 lb. per sq. in.

If the load remains in steady action, nothing further occurs. If, however, the stress is reversed—*i. e.,* if the metal is being subjected to alternating stress—then this slight amount of slip will also be reversed, particularly as the slip surfaces will still be covered with the temporarily mobile layer of amorphous metal. Such reversal will be repeated with each reversal of the applied stress, and at each successive slip the layer of amorphous material will be increased. After a time, however, by virtue of its temporary mobility, this film of quasi-liquid metal will be squeezed out between the gliding surfaces, and the site of the initial minute slips will develop into a fine crack. As this process continues, that particular crystal soon begins to lose its strength, and additional stress is thereby thrown upon its immediate neighbours, which undergo slip and gradual disintegration in the same way. Ultimately, the crack or flaw thus originated works

its way across the entire section of the metal, and failure of the piece results. If the action has been fairly rapid, *i. e.*, if the stress was high enough to produce somewhat rapid disintegration by repeated reversals of slip, the resulting fracture exhibits the crystal faces upon which slip has taken place as a number of bright facets resembling those produced in a 'brittle' shock fracture, and it is this appearance which has led to the mistaken idea that alternating stresses cause metal to 'become crystalline'. Actually, as we have seen, the metal is crystalline from the beginning, never really 'fibrous', and the 'fibrous' or 'crystalline' appearance of the fractures depends on the mechanism of fracture, and not on any change in the crystalline structure of the metal. Mr. Prichard.

"The explanation of fatigue fracture which has just been given, although it has been deduced from the general character of plastic deformation by slip, was first given by Ewing and Humfrey, as the result of direct experimental observations in which they watched the formation of slip-bands in certain crystals, and their gradual growth into cracks on the polished and etched surfaces of pieces of Swedish iron submitted to the Wöhler test."*

It is stated in the paper that experiments by Wöhler during the period, 1858-1870, indicate that the elastic limit can be raised when part of the stress is constant and part constantly repeated (page 100);† Launhardt devised a formula, following Wöhler's experiments (page 101);† but such formulas are not applicable to the design of bridge members, for the reason that the deformation beyond the yield point is ruinous (page 102).† In epitomizing these facts in the Synopsis (page 73),† the writer hoped to emphasize the caution against relying on any increase above the primitive elastic limit, in designing tension and compression members; and he did not desire to imply, by the statement quoted from the Synopsis by Mr. Stanton, that the strength can be raised above the yield point by repeated stresses "varying from zero to an upper limit."

Mr. Stanton states "that the phenomenon of repeated loadings of a structure from zero to an upper limit is only a particular case of cyclical variations of stress", and he refers to a "valuable paper" by Mr. Bairstow. Mr. Bairstow's conclusions in the paper referred to are as follows:

"It is found that, after a sufficient number of repetitions, iron or steel is capable of adjusting inself to variations of stress, cyclically applied. When this adjustment is complete, the specimen is found to have become perfectly elastic throughout the whole cycle, and fatigue does not occur.

"This adjustment to a given cycle is possible because the limits of elasticity are not fixed, but can be raised or lowered by repetitions of stress.

* "An Introduction to the Study of Physical Metallurgy", by Walter Rosenhain, pp. 253–254.

† *Proceedings*, Am. Soc. C. E., for January, 1916.

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"During the adjustment of the elastic limits to a given cycle of stress a change of length occurs in the specimens, which is the same as the extension observed in an ordinary tensile test when the yield stress is exceeded. For cyclically applied stress a similar extension occurs, even when the maximum stress in the cycle is less than the static yield stress.

"The greater the extension of the specimen during adjustment, the greater are the amounts by which the elastic limits are raised.

"The power of adjustment is limited, and if the range of stress in the imposed cycle is sufficiently great, the specimen becomes or remains inelastic, and work is performed during each cycle. This work is expended in moving portions of the crystals relatively to one another, and is probably associated with microscopic slip-lines which gradually develop into cracks, ultimately causing fracture of the specimen."*

In addition to the experiments on repeated stresses to which Mr. Stanton refers, Mr. Bairstow made some successive tests in tension and compression on axle steel (which had first been subjected to a cycle of alternate stresses of sufficient duration to secure equal elastic resistance of the metal to tension and compression), and obtained the following results:

"Following a final load of 18.6 tons per sq. in. in tension, the specimen was heated in boiling water for 15 minutes. Test No. 2 showed that the specimen was still elastic at the same load. In compression the limit was reached at about 8.5 tons per sq. in., and the load was continued to 13.28 tons per sq. in. Recovery was again produced, and it was then found that the elastic limit in compression had been raised at least to 13.28 tons per sq. in., but that the tensile elastic limit had fallen to 13.0 tons per sq. in. By alternate heating and testing, the elastic limits were moved about very considerably, but always with the condition that if the tension limit was raised the compression limit was depressed, and *vice versa*."†

Bauschinger and others have tested steel and iron alternately in tension and compression, with somewhat similar results. In the above quoted alternate tension and compression tests by Bairstow, the range of stress between the elastic limits in tension and compression remained nearly constant at about 27 tons per sq. in., against an original yield point of 24.9 tons per sq. in. On the other hand, some re-tests of eye-bar steel at the Watertown Arsenal, after a rest of 3 years and 3 months, had a range between elastic limits of from 82 000 to 98 000 lb. per sq. in., against a primitive elastic limit of 34 400 lb. per sq. in., as shown in Table 10.

After referring to the fact that in some cases raising the elastic limit by over-straining in tension reduces it in compression, Rosenhain states:

* "The Elastic Limits of Iron and Steel under Cyclical Variations of Stress", by Leonard Bairstow, *Phil. Trans.*, Royal Society, Vol. 210, p. 37.

† *Ibid*, p. 53.

"It is difficult to see how the formation of hard amorphous layers on surfaces of slip can account for a softening of the metal in relation to compression while producing hardening as against tension."* Mr. Prichard.

TABLE 10.—RE-TEST OF EYE-BAR STEEL.

Compiled from Watertown Arsenal Report, 1890, p. 731.

Original Eye-bar { Elastic Limit 34 400 lb. per sq. in. / Strained to 54 350 " " " "

Specimens from bar tested 3 years and 3 months later.

How specimens were taken.	Unannealed Specimens. Elastic Limit per Square Inch.		Annealed Specimens. Elastic Limit per Square Inch.	
	In tension.	In compression.	In tension.	In compression.
Crosswise	40 000	51 000	40 000	43 000
Diagonally	40 000	47 000	42 000	40 000
Lengthwise	63 000	35 000	47 000	42 000

It is not at all necessary to attribute paradoxical qualities to the "amorphous layers" to explain the softening of the metal in relation to compression which sometimes results from over-straining in tension, as it can be explained much better by the changes which occur in the balanced internal stresses whenever the metal is over-strained.

In 1848, James Thomson (the elder brother of Lord Kelvin), an engineer and eminent physicist, by a pure effort of scientific reasoning, and without any tests on the subject to guide him, deduced and published† the following theory:

"The considerations adduced seem to me to show clearly that there really exist *two elastic limits* for any material, between which the displacements or deflexions, or what may in general be termed the changes of form, must be confined, if we wish to avoid giving the material a set, or, in the case of variable strains, if we wish to avoid giving it a continuous succession of sets which would gradually bring about its destruction; that these two elastic limits are usually situated one on the one side and the other on the opposite side of the position which the material assumes when subject to no external strain, though they may be both on the same side of this position of relaxation; and that they may therefore with propriety be called the *superior* and the *inferior limit* of the change of form of the material for the particular arrangement which has been given to its particles; that these two limits are not *fixed* for any given material, but that, if the change of form be continued beyond either limit, two new limits will, by means of an alteration in the arrangement of the particles of the material, be given to it in place of those which it previously possessed."‡

* "An Introduction to the Study of Physical Metallurgy", p. 252.

† In an article in the *Cambridge and Dublin Mathematical Journal*.

‡ "Encyclopædia Britannica", 9th Ed., Vol. VII, p. 800.

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Thomson illustrated his theory by demonstrating theoretically, for a particular case of torsion, that a bar, originally free from initial internal stress, could have its elastic resistance to torsion increased one-third in the direction of the straining force, and decreased one-third in the opposite direction, by a certain degree of over-straining; and he pointed out that the same principles are applicable to beams subjected to transverse loading. He did not allude to direct tension and compression, but his theory can readily be extended to such cases. For illustration: if a pair of soft steel eye-bars, with an elastic limit of 30 000 lb. per sq. in., and a pair of hard steel eye-bars of the same size, with an elastic limit of 50 000 lb. per sq. in., are symmetrically coupled in the same link by pins, and supported laterally, they can be alternately strained in tension and compression to 30 000 lb. per sq. in. without exceeding their elastic limits, provided they are free from flaws and initial internal stresses and have perfect elasticity to the elastic limit; thus showing the range of the elastic field for the link between the superior and inferior limits of its elasticity to be 60 000 lb. per sq. in. If, however, the link is strained in tension to the point where the tension in the hard steel bars is just below their elastic limit, the tension in the soft bars will be very little above 30 000 lb. per sq. in., and in the link as a whole it will be about 40 000 lb. per sq. in.; and, after the link is relieved of its load, the soft bars will be strained to 30 000 minus 40 000, or 10 000 lb. per sq. in. in compression, and the hard bars to 50 000 minus 40 000, or 10 000 lb. per sq. in. in tension. A subsequent compressive load of 20 000 lb. per sq. in. applied to the link will then strain the soft bars to their elastic limit in compression of 30 000 lb. per sq. in.; or a subsequent tensile load of 40 000 lb. per sq. in., applied to the link, will then strain them to their elastic limit in tension of 30 000 lb. per sq. in., and the elastic field, as before, will be 60 000 lb. per sq. in. If the compressive load, instead of being 20 000 lb. per sq. in., were enough greater (10 000 lb. per sq. in. of link greater, or 20 000 lb. per sq. in. of hard bars, which must now carry all the additional load, the soft bars being the "lazy horse") to strain the hard bars to 30 000 lb. per sq. in., all the bars, hard and soft, would become entirely free from balanced internal stresses when the link was relieved of its load.

When the hard and soft metals, instead of being segregated in separate bars, are intimately mixed in each bar, the action is more complicated, but the principles which govern are the same.

According to Thomson's theory, initial internal stresses can be eliminated and the elastic field shifted at will by over-straining.

Thomson's theory takes no account of the mobile or viscous films of metal which result from over-straining,* nor of the hardening pro-

* Subsequent to the promulgation of Thomson's theory of over-straining, he wrote a paper, in 1861, on crystallization and liquefaction as influenced by stresses tending to change of forms in crystals.

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duced by their resolidification. Instead, he based it in part on the tentative proposition: "That no change in the hardness of the substance composing the material has resulted from the sliding of its particles," after it has been strained beyond its elastic limit.

The viscous films will solidify and cement the adjacent crystalline surfaces during a rest, whether the metal is free from stress or is stressed, or even while the stress is fluctuating, provided the fluctuations are not alternations.

Moderate over-straining followed by rest or by only moderate fluctuations tends to increase the elastic limit of the metal by liquification and resolidification in harder, stronger form of the weakest films or portions; that is, the portions having the lowest elastic limits, and this tends to increase the elastic field, as illustrated in Table 10.

Alternations of stress appear to be very fatiguing by hindering the resolidification of the viscous metal and by squeezing it from between the sliding crystalline surfaces, and thus producing permanent injury and weakness in the form of cracks.

Alternations of stress may actually take place when repeated stresses seem to be all of one kind; for instance, in the case of the link of soft and hard steel bars, previously analyzed, repeated loads from zero to 40 000 lb. per sq. in. would involve repeated alternations from 30 000 lb. per sq. in. tension to 10 000 lb. per sq. in. compression.

If at any time the stress fluctuates without rest and the fluctuations exceed twice the elastic limit of what is at that time the weakest portion of the metal, over-straining and stress reversals, the conditions which make for permanent fatigue, are bound to ensue, no matter how well the elastic field is adjusted to the conditions; and even when the range of fluctuations exceeds simply the elastic limit of the said weakest portion, over-straining and stress reversals are likely to ensue if the conditions as regards balanced internal stresses are sufficiently unfavorable.

Any piece of steel manufactured by hot-rolling or hot-forging is, to a greater or less extent, strained initially by balanced internal stresses, besides which it contains microscopic flaws which cause unequal distribution of stress from external forces; hence (assuming that its condition as regards balanced internal stresses has not been adapted by previous suitable over-straining and rest treatment to the particular stress conditions to which it is to be subjected) the range between the limits within which the loading can continuously fluctuate without producing both mobile metal and alternate stresses, must in practice for such a piece be less than twice the elastic limit of its weakest constituent metal. The elastic field of such a piece is naturally normal; that is, its yield point and the imperfections in elasticity within the yield point may naturally be expected to be about the same in tension as in compression; and the range of fluctuation, which will

Mr. Prichard. not, at the start of a continuous series of stress fluctuations, produce more mobile metal than is consistent with subsequent endurance, will be greatest when the fluctuation is between equal tension and compression, less when the fluctuation is between zero and an upper limit of tension or compression, and least when the fluctuation is between two limits of the same kind of stress, one of which is the greatest possible.

Bauschinger, Unwin, Stanton, Bairstow, and others who have critically studied cycles of stress and compared the numbers of repetitions necessary to produce rupture at different stress intensities, have concluded, after plotting the curves of rupture, that these curves indicate certain limiting stress intensities, for different materials, below which rupture would not occur, no matter how often the cycles were repeated. Mr. Moore, however, does not accept the conclusions of these experimenters and analysts. Instead, he states:

"Professor Basquin, of Northwestern University, has pointed out that, for a considerable range of stress, the results of repeated stress tests of metals are well represented by an exponential equation."

The British experimenters, Eden, Rose, and Cunningham, and the American experimenters, Upton and Lewis, also pointed out such an apparent relation. Mr. Moore further states that, as a result of investigations on which he and Mr. F. B. Seely have been engaged:

"The following modification of Basquin's formula is proposed:

$$S = \frac{B}{(1 - Q)\,N^{0.125}}, \quad * * *$$

in which

S = fiber stress necessary to cause failure;
N = corresponding number of repetitions of stress (the 'life' of the piece);
Q = ratio of minimum stress applied to maximum stress ($Q = 0$ for load varying from zero to a maximum, $Q = -1.0$ for a completely reversed load);
B is an experimentally determined constant."

Mr. Moore has stated to the writer:

"This equation is proposed as a working formula, and is based on test results near the minimum for the test data available. Many individual tests, especially those made on rotating shaft specimens under bending, show higher results than are given by this formula."

According to this formula, any cycle of stress, if successively repeated, will eventually cause failure.

The Watertown Arsenal's endurance tests of shafts of open-hearth steel of various grades, as given in Table 3, by covering a much greater range of repetitions of cycles of stress than is usual in experiments of this kind, afford a good opportunity to try out Moore's formula and the opposite contentions of the other school of analysts cited. The

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writer has accordingly diagrammed these tests. They all plot quite close to smooth curves, which, as far as they go, and they go far enough to be very assuring to structural engineers, support the contention that there are limits within which cycles of stress can be continuously repeated without resulting in failure (it should be remembered, however, that mechanical engineers have to do with repetitions of stress far outnumbering anything in these tests; for instance, the rotations of shafts of steam turbines in a few years amount to billions). One of these curves is shown in Fig. 14, together with the locus of Moore's formula, which, it will be observed, does not agree with the experi-

ENDURANCE TESTS OF ROTATING SHAFTS OF 0.82 CARBON STEEL,
1 IN. IN DIAMETER

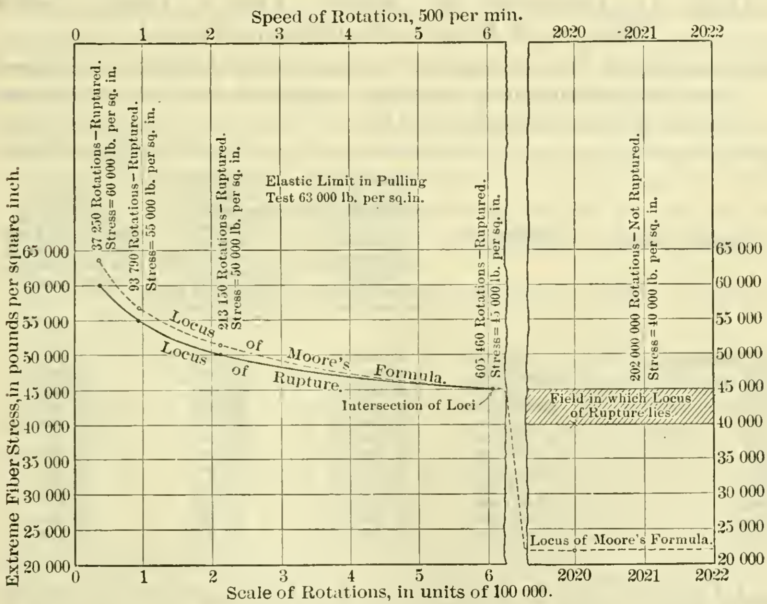

FIG. 14.

ments. Mr. Moore suggests, in a letter to the writer, "A lower value of exponent than 0.125 would give better agreement with these particular test results."

To make a further comparison of Moore's formula with the experiments in Table 3: first, the values of B were obtained for each grade of steel, by taking for each case the values of N and S from the test in which the number of rotation was closest to one million; second, by computing in each case from these values the value of S for the maximum number of rotations given in the table; third, by placing the

Mr. Prichard. values of S, thus computed from Moore's formula, in juxtaposition with the values of S corresponding to the actual results of experiments. This comparison is given in Table 11.

From Table 11 it appears that the various grades of steel sustained, without failure from fatigue, millions of alternations of stress varying for the different grades from 49 to 87% in excess of the failure stress indicated by Moore's formula. The failure of the 0.34 carbon steel at 63 667 320 rotations was evidently due to wearing and scoring at the bearings, and not to fatigue.

Some of the shafts recorded in Table 3, after being subjected to many millions of alternations of stress without rupture, as indicated in that table, appear to have had their capacity for endurance enhanced

TABLE 11.—Comparison of Moore's Fatigue Formula with Results of Experiments Given in Table 3.

The constant, in Moore's formula, for each grade of steel, was obtained from the experiment in which the number of rotations was nearest to one million; indicated as (1).

Grade of steel.	Number of rotations.	Extreme fiber stress corresponding to results of experiments as given in Table 3, in pounds per square inch.	Constant in Moore's formula, for each grade of steel, as computed from experiments (1), in pounds per square inch.	Extreme fiber stress computed from Moore's formula, in pounds per square inch.
0.17 carbon...........	293 510	40 000 (1)	386 800	40 000
0.17 "	100 000 000	30 000 (2)	386 800	19 340
0.34 "	166 360	45 000 (1)	404 400	45 000
0.34 "	63 667 320	40 000 (3)	404 400	21 400
0.55 "	900 720	35 000 (1)	388 600	35 000
0.55 "	75 006 000	30 000 (2)	388 600	20 140
0.73 "	238 212	50 000 (1)	470 000	50 000
0.73 "	58 400 000	40 000 (2)	470 000	25 130
0.82 "	605 460	45 000 (1)	475 300	45 000
0.82 "	202 000 000	40 000 (2)	475 300	21 770
1.09 "	433 380	40 000 (1)	405 200	40 000
1.09 "	175 280 000	35 000 (2)	405 200	18 730

(1) Ruptured; (2) Not Ruptured; (3) At 63 432 700 rotations, bar run hot; middle bearing melted. Bar scored at center from head of screw that holds up middle bearing fixture; bar also scored at the south middle bearing. New bearings put in, and test resumed. At 63 667 320 bar ruptured midway between bearings at a score mark made by head of screw which holds up middle bearing fixture.

by the straining they had undergone, as they were subsequently subjected to endurance tests at higher loads, which they then sustained for more rotations than the shafts which had not been subjected to previous tests; for instance, the 0.17 carbon shaft, after resisting 100 000 000 rotations at a stress of 30 000 lb. per sq. in., stood 6 470 460 rotations at 35 000 lb. per sq. in. before rupture, against 5 757 920 rotations at 35 000 lb. per sq. in. of a shaft not previously tested; the 0.73 carbon shaft, after resisting 58 400 000 rotations at

40 000 lb. per sq. in. without rupture, stood 1 000 rotations at 45 000 plus 1 000 at 50 000 plus 1 000 at 55 000 plus 74 040 at 60 000 lb. per sq. in. before rupture, against 55 390 rotations at 60 000 lb. per sq. in. of a shaft not previously tested; the 1.09 carbon steel, after resisting 175 280 000 rotations at 35 000 lb. per sq. in. without rupture, stood 1 000 rotations at 40 000 plus 1 000 at 45 000 plus 1 000 at 50 000 plus 1 000 at 55 000 plus 17 350 rotations at 60 000 lb. per sq. in. before rupture, against 17 540 rotations at 60 000 lb. per sq. in. in a shaft not previously tested; an 0.82 carbon shaft, not listed in Table 3, after resisting 62 076 660 rotations at 35 000 lb. per sq. in. without rupture, stood 140 830 rotations at 55 000 lb. per sq. in. before rupture, against 93 790 rotations at 55 000 lb. per sq. in. of a shaft not previously tested.

The only shaft which on re-testing did not on its face plainly show increased capacity for endurance as a result of the previous endurance test under moderate stress was the 0.55 carbon one. This shaft, after resisting 75 006 000 rotations at 30 000 lb. per sq. in. without rupture, was subsequently subjected once to 100 rotations and eight times to 1 000 rotations (8 100 in all) at 60 000 lb. per sq. in., with 1 334 060 rotations at 30 000 lb. per sq. in. interspersed between times, and then ruptured after 3 280 additional rotations at 30 000 lb. per sq. in. Against this, a shaft not previously tested resisted 12 490 rotations at 60 000 lb. per sq. in. before rupture.

Mr. Moore, to whom Table 11 was submitted in advance of publication, stated in reply:

"The divergence of test results from the proposed exponential formula is noted by Basquin, by Upton and Lewis, and by Moore and Seely. The advocates of an exponential formula for repeated stress calculations claim that the test data for numbers of repetitions of stress greater than ten million are very few, that while most test data for high values of N shows results above those given by exponential formulas, some data (Wöhler) seems in fair agreement with those formulas, and that in our present state of ignorance as to results of long-time repeated stress tests (which must continue for at least ten years longer, since the European war has caused the cessation of most, if not all, of the long-time tests now in progress) some formula which assumes that the same destructive action which occurs under high stresses will continue to act with diminished intensity under low stresses is a safer guide for the designer than is a fixed endurance limit, below which destructive action is assumed to cease. For structures the stresses given by the exponential formula and those given by the older endurance limits are about the same. For high-speed machinery the exponential formulas give lower stresses than do the old endurance limits.

"Messrs. Moore and Seely have attempted (in their paper before the 1915 meeting of the American Society for Testing Materials) to modify their proposed formula for certain cases by the addition of a 'probability factor' which is given as $(1 + 0.015\ N^{0.125})$. This factor

Mr. Prichard. brings about a somewhat better agreement between the formula and results of most repeated stress tests in which N is greater than ten million. The proposed factor was purposely chosen to give conservative results."

The writer will not digress from the subject of his paper by including a discussion of the endurance of high-speed machinery parts, with their likelihood of accumulative vibration through synchronization of vibratory and loading periods, to centrifugal forces from unintentional and unapparent eccentricities in revolving masses, and to instability at critical or "whirling speeds", in addition to pulling, pushing, bending, and twisting loads; but, simply as a caution against snap judgments as to safety in proportioning such parts, he calls attention to the paradox that in some cases it is safer to use a shaft with a small diameter than a shaft with a large one. For instance, in a certain type of De Laval turbines the wheel with its shaft will revolve safely and smoothly at a tremendous speed (at a rate of 30 000 rev. per min. or 15 768 000 000 per year in the 5-h.p. turbines) about an axis which passes almost exactly through the actual center of the revolving mass, as distinguished from the nominal center, for the reason that the shaft being slender is flexible; whereas, if it were of much larger diameter, and correspondingly stiffer, there would be danger of intense bending stresses and of other detrimental phenomena from centrifugal force and vibration.

Professor Howe introduces the question of the effectiveness of raising the elastic limits of steel and iron by the cold-working of the material prior to putting it in service. There is no doubt that, when the cold-working strains are not too severe, the endurance to constant loads is increased. In this regard Thurston's endurance tests of wires, as given in Table 12, are pertinent. It is also very probable: first, that the material acquires a capacity for enduring stresses much higher than its primitive elastic limit before it was cold-worked, provided the range of variation in stress is kept somewhat less than the said primitive elastic limit; second, that, for occasional loads, with long intervals of rest between them, the range of variation in stress is much greater than the said primitive elastic limit. Looking at the question from a theoretical standpoint, it may also be, especially in the case of wire, that such a large proportion of the metal has been made viscous, and resolidified in much stronger form, that the elastic field will be enlarged, in some cases perhaps greatly enlarged, even for resistance to continuous cycles of stress. The question is one which can only be answered with any certainty by experience and by comparative endurance tests. Professor Howe cites some tests, but not enough to be conclusive, in his valuable and interesting article on the important question: "Are the effects of Simple Over-strain Monotropic?"* The

* *Proceedings*, Am. Soc. for Testing Materials, Vol. XIV, Part 11 (1914), p. 9.

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writer does not know of many others, but presents in Table 13 a few, which are pertinent, on rotating shafts turned down from plain and twisted iron rods. It is not safe to draw conclusions from a few cases, but on their face the tests in Table 13 indicate: first, that the fourth turn of the rod strained the metal too severely; second, that the cold-twisting increased the length of the endurance to a given alternating stress. Whether or not the cold-twisting permanently increased the elastic field of resistance to continuous alternations of stress does not appear.

The enhancement of the elastic limit by cold-working affords an interesting field for experimental and theoretical investigation, and such investigation would be of much practical value to the mechanical engineer, and also, as regards wire cables, to the structural engineer. In general, however, the steel in which the structural engineer is interested is hot-rolled, hot-forged, or cast.

The stresses which are developed in structures vary in intensity, and, even when the loads are frequently applied, there are long intervals between the stresses of greatest intensity and between the greatest extremes of stress. It is the difference between the frequency of the recurrence of such extremes and the recurrence of the extremes in endurance tests that the writer had in mind in making the statement, on page 96,* quoted by Mr. Stanton. High stresses only slightly within the primitive yield point, repeated or even alternated at long intervals would probably do little injury beyond a slight permanent deformation to tension members and stiff compression members, provided the metal had not been previously weakened by a number of frequent repetitions of great variations in stress.

TABLE 12.—(THURSTON'S TABLE NO. 11)† ENDURANCE OF IRON UNDER DEAD LOADS.

Per cent. maximum static load.	TIME UNDER LOAD BEFORE FRACTURE.	
	Hard, unannealed wire.	Soft, annealed wire.
95	8 days	3 minutes.
80	35 days	5 minutes.
85	Unnoted, but 1 or 2 years	261 days.
80	91 days	266 days.
75	Unbroken after several years	17 days.
70	Same results	455 days.
65	Same results	455 days (probable jar).

" Some of these wires were still unbroken in 1888, after 15 years' loading."

* *Proceedings*, Am. Soc. C. E., for January, 1916.

† *Transactions*, Am. Soc. C. E., Vol. XLI, p. 516.

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TABLE 13.—THE EFFECT OF TWISTING RODS OF "BURDEN'S BEST IRON" ON THE ENDURANCE OF ROTATING SHAFTS MADE THEREOF.

Shaft 1 in. in diameter, 37 in. between supports, loaded on 4 in. at center.

From Watertown Arsenal Report, 1903, p. 337.

Previous treatment of iron. Number of turns in 45 in.	Computed maximum fiber stress per square inch.	Number of revolutions. Speed, 500 per minute.	Remarks.
None (natural state)..	20 000	1 000 000	Not ruptured.
	25 000	1 716 380	Ruptured.
		2 716 380	Total rotations.
2...........	25 000	3 032 130	Ruptured.
3...........	25 000	12 074 960	Ruptured.
4...........	25 000	7 043 080	Ruptured.

Mr. Stanton calls attention to a phenomenon recorded in Mr. Bairstow's valuable paper* on the range of the elastic limits, as follows:

"Experiments on an axle steel with a yield point of 24.9 tons per sq. in. showed that in repeated loadings from 0 to 23.2 tons per sq. in. no sign of want of elasticity occurred until after 6 000 loadings, when a permanent extension of the order of the yield took place."

That there should be a difference in yield points in different specimens of the same steel is not remarkable. That the difference in the cases referred to was due to the manner of developing the yield seems probable. As the ultimate tensile strength of the specimen of axle steel which developed the yield point of 24.9 tons was 38.2 tons, the ratio of yield point to ultimate was 65.1%, or, for a yield point of 23.2 tons, 60.7 per cent.

It is doubtful whether a primitive elastic limit much in excess of 60% of the ultimate is a direct criterion of the maximum load which can be continuously repeated from zero to a maximum without causing failure. In some cases of high ratios the change from nearly perfect elasticity to rapid yield is so sudden and pronounced as to suggest that a slight change in conditions would have caused the metal to yield under a considerably lower stress; for instance, a piece of steel tested at the Watertown Arsenal† for comparison of testing machines, at 40 000 lb. per sq. in. or 82.9% of its ultimate tensile strength, had no set in a gauged length of 8 in., and had a modulus of elasticity of 30 000 000; but, at 40 600 lb. per sq. in. it suddenly yielded, and the load fell to 30 000 lb. per sq. in., which is 62.2% of the ultimate tensile strength of 48 240 lb. per sq. in. This specimen had the greatest drop

* *Phil. Trans.*, Royal Society, Vol. 210, p. 35.

† Report for 1904, p. 197.

at the yield point which the writer has ever seen recorded. Ordinarily, the drop is within 10% of the load at the yield point. In general, the drop in load at the yield point is greatest for soft and medium steels with high elastic limits, and it decreases with decrease in the ratio of elastic limit to ultimate and with increase in ultimate. Mr. Prichard.

For structural purposes, a pronounced yield is failure, and its careful observation in tests is of value accordingly. Low elastic limits which mark the beginning of a general yield are critical, but low elastic limits which are not followed within a few thousand pounds by a critical deformation are not very detrimental to tension members and stiff compression members, as their elasticity can be perfected by straining in service at the expense of a little permanent set. Such low elastic limits are caused, as explained by Mr. Howard, by initial internal stresses. The effect of such stresses on compression members, as also explained by Mr. Howard, is nearly akin to eccentricity. In other words, these stresses cause a deflection in compression members where, under ideal conditions, there would be none. This is one of the elements of weakness for which suitable provision is or should be made by use of some reasonable column formula.

Mr. Lynch does not present any data regarding the deformation which followed the "true elastic limit of 15 000 lb. per sq. in. or less" (which he states that plates with a tensile strength of more than 60 000 lb. per sq. in. often have), nor any other information from which to judge whether this "true elastic limit", as determined by the extensometer, was the real elastic limit of the steel, or simply the elastic limit of the piece in whatever condition as regards initial internal stresses it happened to be; which latter, owing to the initial internal stresses, may be much less, as Mr. Howard has pointed out. Eccentricity in loading in the testing machine, as Mr. Howard has also pointed out, and the non-observance of the practice of allowing "test pieces to 'rest' for a day or two before pulling", as pointed out by Mr. Speller, may likewise result in extensometer readings which are below the "real elastic limit" of the material.

Mr. McCulloch has cited eye-bars for which the micrometers indicated permanent sets under pulling loads of 5 000 lb. per sq. in.; and the writer could cite many other cases, but he does not know of any case in which the test showed that the steel of which the piece tested was composed had a real elastic limit as low as "15 000 lb. per sq. in.", nor of any case in which a piece of steel tested under repeated (not alternated) loads failed under a load of less than 35 000 lb. per sq. in., except one bar (which had unfilleted re-entrant angles where reduced in section and, therefore, was not a criterion) tested by Wöhler to failure on the 274 969th repetition of a load of 31 100 lb. per sq. in. Tests of steel and iron to failure under thousands and millions of repetitions of simple tension were made by Wöhler, as given in Table

Mr. Prichard. 14, and by Bauschinger, as given in Table 15. The writer does not know of any others.

There is some difference between Mr. Lynch's claim that "Plates having a tensile strength of more than 60 000 lb. per sq. in. may, and often do, have a true elastic limit of 15 000 lb. per sq. in. or less" and Dr. Waddell's statement that "The elastic limit for medium bridge steel is 35 000 lb. per sq. in." It is hardly likely that Dr. Waddell wishes to have this general statement taken too literally and without allowance for the differences which may be caused by variation in reduction in rolling and in the temperature at which the steel is rolled, as he has previously published* the yield points indicated in tests made at the Drexel Institute from the same heat of ordinary open-hearth carbon steel, as follows:

12-In. Universal Plates—Heat No. 33 342.

	Section, in inches.	Pounds per square inch.	Percentage of ultimate.
Average of 4 specimens,	1.510 by 0.355	38 800	60.5
" " 4 "	1.510 " 0.475	36 880	57.8
" " 4 "	1.510 " 0.755	33 420	53.8
" " 6 "	1.250 " 1.000	27 380	44.9
" " 2 "	1.250 " 0.995	25 700	43.8

The yield points were indicated by a set of 0.01 in. in 8 in., and were a little lower than indicated by the drop of the beam.

Dr. Waddell had occasion to investigate extensively the subject of the elastic limit, as appears in the valuable paper in which the Drexel Institute tests above cited were published; but there are many engineers who are not familiar with the extent of the differences in reduction in cross-section and in the temperature at which reduced, incident to the manufacture of structural steel (with its wide range of shapes and sizes), and who do not realize the effects on the elastic limit of the reduction and of the temperature at which the reduction is made. In this regard, interesting tests were made at the Watertown Arsenal of bars from an open-hearth steel ingot, forged down to different degrees and at different temperatures, as given in Table 16.

The writer fully appreciates the worth of the previous efforts of Dr. Waddell, Mr. Molitor, and other eminent engineers in combating the application to bridge design of Launhardt's and similar fatigue formulas. Largely through their efforts, such use of these formulas has declined, but, unfortunately, has not ceased. It is noteworthy, however, that in this discussion the application of such formulas to bridge design has not had a single champion.

* *Transactions*, Am. Soc. C. E., Vol. LXIII, p. 264.

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TABLE 14.—WÖHLER'S TESTS OF STEEL AND IRON BARS BY REPEATED TENSIONS BETWEEN DEFINITE LIMITS.

Material.	Form of bar.	Repeated Pulling Loads — From: Pounds per square inch.	To: (Bar broke.) Pounds per square inch.	To: (Bar did not break.) Pounds per square inch.	To: Ratio to ultimate. Percentage.	Number of repetitions of load.	Primitive ultimate tensile strength, in pounds per square inch.
Iron axle, Phœnix Co.	*A*	0	46 700	....	107.6	800	
	A	0	42 800	....	98.6	106 910	
	A	0	38 900	....	89.6	340 853	2 specimens.
	A	0	35 000	....	80.6	409 481	43 000
	A	0	35 000	....	80.6	480 852	43 800
	A	0	31 100	....	71.7	10 141 645	
	A	19 400	42 800	....	98.6	2 373 424	Average.
	A	23 300	....	42 800	98.6	4 000 000	43 400
	B	0	34 800	....	80.2	37 828	
Krupp's axle steel...	*A*	0	77 800	....	82.3	18 741	5 specimens.
	A	0	68 000	....	72.0	46 286	99 800
	A	0	58 300	....	61.7	170 170	101 200
	A	0	53 200	....	56.3	123 770	101 200
	A	0	48 600	....	51.4	473 766	85 100
	A	0	....	46 700	49.4	13 600 000	85 100
	A	0	....	44 700	47.3	13 200 000	
	A	48 600	....	77 800	82.3	1 801 000	Average.
	A	38 900	....	77 800	82.3	12 100 000	94 500
	A	34 000	....	77 800	82.3	12 100 000	
Krupp's axle steel..	*B*	0	48 600	....	51.4	23 546	
	B	0	44 700	....	47.3	33 486	
	B	0	40 900	....	43.3	65 658	
	B	0	38 900	....	41.2	75 343	As above.
	B	0	35 000	....	37.0	208 883	
	B	0	31 100	....	32.9	274 970	
	B	0	....	29 200	30.9	1 100 000	
Cast iron from locomotive cylinder......	*A*	0	15 500	....	....	3 140	
	A	0	13 600	....	....	4 000	
	A	0	12 700	....	....	10 342	
	A	0	11 700	....	....	45 028	
	A	0	10 700	....	....	78 682	
	A	0	10 200	....	....	27 885	
	A	0	10 200	....	....	35 599	
	A	0	9 700	....	....	208 439	
	A	0	....	9 700	....	7 200 000	
	A	0	....	9 700	....	7 600 000	

The bars marked *A* had well-rounded corners at the point where the small middle part of the test bar joined the enlarged end. Those marked *B* had square corners.

Three equivalents, in pounds per square inch, have been given by different authorities for the centner zoll: namely; 97.24, 104 and 107, accordingly as they used the old German or assumed the old Prussian or the present German value for the centner. The old German centner was 100 lb. (Century Dictionary); the old Prussian pound was 467.7 grams (Johnson's and Brockhaus' Encyclopædias); the old Prussian zoll was 1.03 English inches (Webster's Dictionary), which brings 97.24 lb. per sq. in. as the equivalent of the centner zoll; this value was used in computing the above.

"According to Bauschinger (Meth. aus Mech.-Tech. Lab. in München, Heft 13, p. 36, 1886) the centner per zoll in which Wöhler gives his results is equivalent to 6.837 kilos per square cm." or 97.24 lb. per sq. in. (Encyclopædia Britannica, 9th Edition, Vol. XXII, p. 601).

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TABLE 15.—Bauschinger's Tests of Steel and Iron by Repeated Tensions between Zero and Sundry Upper Limits.

Number of Repetitions of Load are given to the nearest 10 000.

Material.	Primitive elastic limit, in pounds per square inch.	Primitive ultimate tensile strength, in pounds per square inch.	Repeated Loads.		Ratio of load to elastic limit. Percentage.	Ratio of load to ultimate. Percentage	Number of repetitions of load.
			Test piece broke. Pounds per square inch.	Test piece did not break. Pounds per square inch.			
Mild steel plates......	34 900	63 800	58 700	......	167.9	91.9	40 000
	34 900	63 800	58 700	......	167.9	91.9	70 000
	34 900	63 800	58 700	......	167.9	91.9	110 000
	34 900	63 800	58 700	......	167.9	91.9	340 000
	34 900	63 800	58 700	.....	167.9	91.9	490 000
	34 900	63 800	51 500	......	147.4	80.7	160 000
	34 900	63 800	51 500	......	147.4	80.7	320 000
	34 900	63 800	51 500	......	147.4	80.7	440 000
	34 900	63 800	51 500	......	147.4	80.7	620 000
	34 900	63 800	51 500	......	147.4	80.7	760 000
	34 900	63 800	44 100	......	126.3	69.1	670 000
	34 900	63 800	44 100	......	126.3	69.1	1 010 000
	34 900	63 800	35 800	......	102.6	56.2	3 550 000
	34 900	63 800	35 800	......	102.6	56.2	6 680 000
	34 900	63 800	35 800	......	102.6	56.2	7 350 000
	34 900	63 800	......	35 800	102.6	56.2	11 030 000
Mild steel boiler plates......	39 400	59 600	47 000	......	119.3	78.9	400 000
	39 400	59 600	47 000	......	119.3	78.9	490 000
	39 400	59 600	47 000	......	119.3	78.9	880 000
	39 400	59 600	41 900	......	106.3	70.3	400 000
	39 400	59 600	41 200	......	104.5	69.2	4 850 000
	39 400	59 600	36 700	......	93.5	61.7	340 000
	39 400	59 600	......	41 900	106.3	70.3	4 870 000
	39 400	59 600	......	36 700	93.5	61.7	6 540 000
Thomas steel axle........	39 400	89 800	58 700	......	148.8	65.3	60 000
	39 400	89 800	58 700	......	148.8	65.3	220 000
	39 400	89 800	58 700	......	148.8	65.3	620 000
	99 400	89 800	44 100	......	111.9	49.1	9 040 000
	39 400	89 800	......	36 500	92.6	40.6	9 580 000
Thomas rail steel.......	42 600	87 400	58 700	......	137.8	67.2	560 000
	42 600	87 400	58 700	......	137.8	67.2	570 000
	42 600	87 400	44 100	......	103.7	50.5	7 910 000
	42 600	87 400	36 700	......	86.3	42.0	10 190 000
Bar iron.....	33 200	59 800	44 100	......	133.1	73.7	670 000
	33 200	59 800	38 500	......	116.2	64.4	9 310 000
	33 200	59 800	30 900	......	93.2	51.7	16 480 000
	26 400	59 600	44 100	......	166.9	74.1	240 000
	26 400	59 600	44 100	......	166.9	74.1	640 000
	26 400	59 600	44 100	......	166.9	74.1	840 000
	26 400	59 600	36 700	......	138.9	61.6	7 400 000
	26 400	59 600	29 600	......	111.9	49.6	9 110 000
Wrought-iron plate..	15 200	56 400	36 700	......	239.7	65.1	2 280 000
	15 200	56 400	25 000	......	191.5	52.0	5 180 000
	15 200	56 400	22 100	......	144.0	39.1	5 190 000
	15 200	56 400	15 900	......	103.8	28.2	5 170 000

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TABLE 16.—SUMMARY OF TENSILE TESTS OF BARS FORGED DOWN FROM AN OPEN-HEARTH STEEL INGOT IN THE DIRECTION OF ITS LENGTH, AT DIFFERENT TEMPERATURES AND WITH DIFFERENT AMOUNTS OF REDUCTION.

(From Watertown Arsenal Report, 1909, Vol. 3, p. 896.)

Diameter of specimens, 0.798 in. Sectional area, 0.50 sq. in. Gauged length, 6 in.

No. of test.	Marks.	Reduction under hammer, percentage.	Approximate finishing temperature, in degrees, Fahrenheit.	Elastic limit, in pounds per square inch.	Tensile strength, in pounds per square inch.	Ratio of elastic limit to tensile strength. Percentage.	Elongation. Percentage	Contraction of area. Percentage.
8 658	13 *B*	6.0	1 400	64 000	108 000	59.2	14.6	23.0
8 645	13 *T*	9.2	1 400	67 000	109 800	61.0	17.0	25.2
8 657	12 *B*	16.1	1 400	70 000	111 800	62.6	16.1	29.4
8 643	11 *T*	18.9	1 400	72 000	110 000	65.5	13 1	18.6
8 644	12 *T*	32.2	1 400	70 000	111 400	62.8	16.0	29.4
8 648	3 *B*	2.3	1 600	56 000	105 000	53.3	7.1	9.2
8 634	2 *T*	7.2	1 600	53 000	108 000	49 1	9.1	11.6
8 646	1 *B*	11.5	1 600	61 090	109 800	55.6	13.1	16.2
8 647	2 *B*	27.2	1 600	60 000	110 200	54.4	12.6	16.2
8 633	1 *T*	28.4	1 600	69 000	112 600	61.3	15.5	18.6
8 637	5 *T*	2.5	1 800	50 000	104 800	47.7	7.2	9.2
8 636	4 *T*	5.6	1 800	52 000	108 000	48.1	7.6	9.2
8 650	5 *B*	8.0	1 800	51 000	108 400	47.0	9.5	11.6
8 649	4 *B*	14.7	1 800	59 000	113 000	52.2	8.6	9.2
8 635	3 *T*	28.2	1 800	62 000	112 800	54.9	11.3	14.0
8 655	10 *B*	3.6	2 000	48 000	105 800	45.4	7.8	9.2
8 656	11 *B*	6.1	2 000	49 000	108 400	45.2	12.0	11.6
8 642	10 *T*	10.3	2 000	50 000	108 400	46.1	9.8	11.6
8 654	9 *B*	13.6	2 000	52 000	108 200	48.0	12.3	14.0
8 641	9 *T*	26.5	2 000	55 000	110 400	49.1	13.3	16.2
8 640	8 *T*	31.6	2 000	57 000	111 200	51.2	14.0	25.2
8 638	6 *T*	4.3	2 200	47 000	108 400	43.4	10.5	11.6
8 653	8 *B*	14.5	2 200	51 000	110 600	46.1	12.3	14.0
8 652	7 *B*	21.8	2 200	50 000	109 800	45.6	14.0	23.0
8 639	7 *T*	27.0	2 200	51 000	111 000	45.9	15.1	27.4
8 651	6 *B*	29.6	2 200	55 000	113 000	48.7	16.0	27.4

The writer, as his previous papers* show, is in full sympathy with Mr. Molitor's efforts to secure reasonable safety for bridges when overloaded.

In conclusion, the writer emphasizes the facts: that strength which can only be acquired at the expense of undue deformation is of little value; that original faults in elasticity which can be corrected in service without undue deformation are not critical; that the real strength of any member of a structure is measured by the loads it can

* "Insufficient Provision for Counterstresses in Railroad Bridges", *Transactions*, Am. Soc. C. E., Vol. XLII, p. 547.
"The Proportioning of Steel Railway Bridge Members", *Proceedings*, Engrs. Soc. of Western Pa., Vol. XXIII, p. 344 ; also *Engineering News*, September 19th, 1907, p. 302.

Mr. Prichard. sustain without undue deformation under the conditions of service during the lifetime of the structure, as determined by other causes; that, in judging the real strength of structural members from tests, a knowledge of the principles of physical metallurgy is very useful; and that, in consideration of the conditions of manufacture, considerable variation in the strength of such members, even when made of steel from the same melt, should be expected.

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PAPERS AND DISCUSSIONS

THE FLOW OF WATER IN IRRIGATION CHANNELS

Discussion.*

By Messrs. William S. Aldrich and George Henry Ellis.†

William S. Aldrich,‡ Esq. (by letter).§—This valuable paper illustrates once more the constant tendency of scientific thought in its treatment of natural phenomena. It is from the complex to the simple. After a half century of the Ganguillet-Kutter adaptation of the Chezy formula, itself then nearly a century old, we have had, in the last score of years, to reckon with Bazin's attempt to revert to the simplicity of the Chezy formula. Encouraged in this logical process, the author of this paper boldly attempts the final reduction. It is, however, all the more worthy of an audience, not necessarily because it is the latest, but in that it is based on the unimpeachable data of the Government tests, conducted by the Department of Agriculture. Beyond this we may go, but scarcely at private expense, or college laboratory charge. Mr. Aldrich.

Examining the summary of results, Table 2, we find a tendency of the product, nC, to assume a nearly constant value; that is, this product ranges slightly above and below the value inherent in the type of canal which is usually accepted as representative of the given class of construction. This is shown in Table 9.

Plotting the values for each series, throughout the whole range, we find that the author has selected the value of C which corresponds very nearly to the general average values and the usual grade of construction, as shown in Table 10.

* Discussion of the paper by George Henry Ellis, Assoc. M. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† Author's closure.

‡ Fort Collins, Colo.

§ Received by the Secretary, May 23d, 1916.

Mr. Aldrich.

TABLE 9.

Type.		n.	C.	Product, nC.
Concrete ..	II	0.013	113.5	1.4755
	III	0.014	107.5	1.505
	IV	0.015	99.0	1.485
	VII	0.018	80.0	1.440
Wood......	II	0.013	114.0	1.482
	III	0.014	106.0	1.484
	IV	0.015	99.5	1.4925
	V	0.016	91.0	1.456
Metal......	I	0.011	137.0	1.507
	II	0.015	93.5	1.4025
Earth......	I	0.016	90.5	1.448
	II	0.020	70.3	1.406
	III	0.0225	61.2	1.377
	IV	0.025	52.8	1.320

TABLE 10.

Type.	n.	C (Ellis).	Product, nC.
Concrete channels (similar to III)......	0.014	105	1.470
Wooden channels (between III and IV).	0.0148	100	1.480
Earth channels (similar to III).........	0.0225	60	1.350

Referring to Fig. 3, we find, at several points along the curve, a helpful interpretation of relations between n and C. For example, the following marked points may be noted:

n.	C.	Product, nC.
0.014	105.8	1.4812
0.018	80.3	1.4454
0.0225	60.2	1.3545

These relations are more or less significant; they indicate the very close approximation of the constants selected to the actual conditions prescribed by the usual types of construction. It is thus found that the better types of wooden channels are in the same class as the poorer types of the concrete, though even the poorer types of wooden channels hold up to the concrete remarkably well. The better types of earth channels are in the identical class of the poorer types of the wood. As might be expected, the poorer type of earth channels, within the values, 0.0225 and larger, are in a class by themselves. This grading of the relative values of the constructive types is in strict accordance with the values of the product, nC, used as a criterion, and based on Table 2. The metal channels are also clearly in a class

Mr. Aldrich.

by themselves, with this product ranging from 1.40 to 1.50, Types II and I, respectively.

Fig. 3 is a curve of the nature of an equilateral hyperbola; that is, the product, nC = a constant (approximately). It is not intended to convey the impression that this product is, or should be, constant. The Manning formula, quoted by the author, assumes that it is a constant, and equal to 1.49. We must bear in mind that the exponent of R, in the Manning formula, is 0.67, as compared with an exponent of 0.69 in the Ellis formula.

Mr. Ellis.

GEORGE HENRY ELLIS,* ASSOC. M. AM. SOC. C. E. (by letter)†.—In any discussion of data of this sort, some classification is almost necessary. It seemed logical to make this classification according to the roughness of the channel, and also to base any new formula on experience obtained in the use of an old one. The writer, therefore, arranged the channels in accordance with their computed values of n, which is the method to which Mr. Hazen objects.

The writer agrees with Mr. Harding and Mr. Aldrich that it is desirable to have an expression of the relation between C and n, at least until we become accustomed to thinking in terms of C, and is indebted to both these gentlemen for the formulas submitted by them.

Mr. Harding mentions the Williams formula, $V = CR^{0.67}\ S^{0.54}$, as though it were well known. The writer did not find it, either in Merriman (Ninth Edition) or in Parker's "Control of Water", both standard works on hydraulics; and had not seen it before. The object of this paper was to find a simpler formula for the flow of water, not necessarily the one deduced in the paper, but one which could be accepted by the Profession. Perhaps the Williams formula is the one. It has the different exponent for S which it was hoped would make a better curve of the points in Fig. 4. The exponent of R, 0.67, is well within the range of these points, and might fit them still better had they been obtained by $S^{0.54}$ instead of by $S^{\frac{1}{2}}$. Mr. Harding has deduced a coefficient, also, for it, $C = \dfrac{1.70}{n - 0.002}$, so that it can be used directly with n.

It was thought that where extreme accuracy was not required, the Williams formula might be reduced to $V = CR^{\frac{2}{3}}\ S^{\frac{1}{2}}$, which could be solved on almost any slide-rule, and Tables 11 and 12 have been arranged in order to compare the effects of the various exponents. The difference between $S^{0.54}$ and $S^{\frac{1}{2}}$ is surprising. Perhaps this latter expression, which is essentially the Manning formula, if used

* Fort Shaw, Mont.

† Received by the Secretary, July 10th, 1916.

Mr. Ellis. with a different coefficient, would give results sufficiently close for all practical purposes.

TABLE 11.—POWERS OF RADII.

R	$R^{0.69}$	$R^{0.67}$	$R^{\frac{2}{3}}$
0.2	0.3294	0.3402	0.3420
0.3	0.4357	0.4464	0.4481
0.4	0.5314	0.5412	0.5429
0.6	0.7030	0.7102	0.7114
0.8	0.8573	0.8611	0.8618
1.0	1.0000	1.0000	1.0000
1.5	1.3228	1.3122	1.3104
2.0	1.6133	1.5912	1.5874
3 0	2.1341	2.0878	2.0801
4 0	2.6027	2.5316	2.5198

TABLE 12.—POWERS OF SLOPES.

S	$S^{0.54}$	$S^{\frac{1}{2}}$	S	$S^{0.54}$	$S^{\frac{1}{2}}$
0.00010	0.0069	0.0100	0.003	0.0434	0.0548
0.00013	0.0080	0.0114	0.004	0.0507	0.0632
0.00016	0.0089	0.0126	0.005	0.0572	0.0707
0.00020	0.0100	0.0141	0.006	0.0631	0.0775
0.00025	0.0113	0.0158	0.008	0.0737	0.0894
0.0003	0.0125	0.0173	0.010	0.0832	0.1000
0.0004	0.0146	0.0200	0.013	0.0958	0.1140
0.0005	0.0165	0.0224	0.016	0.1072	0.1265
0.0006	0.0182	0.0245	0.020	0.1209	0.1414
0.0008	0.0213	0.0283	0.025	0.1364	0.1581
0.0010	0.0240	0.0316	0.03	0.1505	0.1732
0.0013	0.0276	0.0360	0.04	0.1758	0.2000
0.0016	0.0309	0.0400	0.05	0.1983	0.2236
0.0020	0.0349	0.0447	0.06	0.2189	0.2450
0.0025	0.0393	0.0500	0.10	0.2884	0.3162

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

Discussion.*

By Messrs. C. A. P. Turner, Henry T. Eddy, L. J. Mensch, and Charles F. Marsh.

C. A. P. Turner,† M. Am. Soc. C. E. (by letter).‡—This paper undertakes to treat the flat plate or slab from the standpoint of the theory of work. It makes the work dependent on Poisson's ratio and moments in selected strips across the center portion of that plate. Mr. Turner.

It is fundamental to the theory that the amount of work done depends on the deflection. Now, a formula which involves work must be such that the deflection can be computed and checked with observed deflection. Otherwise, there is something wrong with the formula, but the author has apparently made no attempt to check his theory by observation. Therefore, it lacks confirmation.

Suppose we compare a circular plate supported at its center with a double cantilever beam supported at the middle. The resisting moment in the cantilever causes stresses along its length, and Poisson's ratio may be disregarded, as it has no effect on the resulting deflection, in accordance with the fundamental equations of extensional stress and strain established a generation ago and accepted by Grashof and all authorities on the subject since then. These equations are as follows:

$$E e_1 = p_1 - K p_2 \qquad (1)$$

$$E e_2 = p_2 - K p_1 \qquad (2)$$

* Discussion of the paper by A. C. Janni, M. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† Minneapolis, Minn.

‡ Received by the Secretary June 26th, 1916.

Mr. Turner. in which K designates Poisson's ratio, p_1 and p_2 are the external applied or apparent stresses per unit of area of cross-section of the plate, which act parallel to the axes of x and y, respectively, if these latter lie in the neutral line of the plate, and e_1 and e_2 are extensional elongations of the plate per unit of length parallel to x and y, respectively. Hence, if p_2 is zero, as it would be in a beam, $Ee_1 = p_1$, the longitudinal deformation, e_1, depends solely on p_1, and determines the deflection.

Thus it is evident that K cannot affect the internal work in a beam in a manner comparable to its effect in a slab, yet Mr. Janni proposes to introduce K into what is substantially a beam formula.

From the mathematical standpoint, Mr. Janni does not work correctly from the general fundamental equations of extensional stress and strain. In deriving his equations for the true moment of the strip parallel to the axis of x, he assumes $p_2 = 0$. In deriving his equation for the strip parallel to the axis of y, he assumes $p_1 = 0$, and, in Equations (1) and (2), if p_1 and p_2 are zero, then the Poisson ratio is eliminated; and yet, having eliminated the Poisson ratio and effect, Mr. Janni arbitrarily inserts a factor involving this ratio in his equation to represent the work which, on the basis of his strip assumption, in deriving his equations for the moment on the strip, has been eliminated. The terms inserted are correct neither for the beam theory nor for the plate theory.

Consider the case of a plate: The deformations due to spherical curvature or bending are radial and circumferential. Assuming that K (Poisson's ratio) is zero, it has been demonstrated* that the work done in a circular direction is equal to that done in a radial direction. Now, radial deformations alone determine the vertical position of the cantilever plate, and though the circumferential deformations necessarily accompany radial deformations, they provide a means of storage of energy which is not involved in nor determines the vertical deflection. Accordingly, in the circular cantilever plate, half the work is done in a manner which produces no deflection. In the slab supported on separated posts, we have a cantilever area about the post, and a suspended span, which is really an inverted plate similar to the cantilever portion about the column, located about the diagonal center of the span so that treatment of the plain cantilever serves for the treatment of the combination of the cantilever and suspended span in a diagonal direction, approximately.

We will now proceed to compare the double cantilever beam and the circular cantilever plate, assuming that the plate and beam have the same thickness, and the same metal, and that each stores an equal quantity of energy, Q; in which case:

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* "Concrete-Steel Construction", by Eddy and Turner, pp. 137-138.

Mr. Turner.

Let W_1 = the load on the cantilever beam uniformly distributed;
W_2 = the load on the cantilever circular plate;
D_1 = the mean deflection of the load in the cantilever beam;
and D_2 = the mean deflection of the load on the cantilever plate;

Since, in the cantilever plate supported at the center, half the work is done in a manner which produces no deflection, as compared with a cantilever beam, the deflection would be reduced one-half. Now,

$$Q = \frac{1}{2} W_1 D_1 = \frac{1}{2} W_2 D_2;$$

but, the amount of energy stored being assumed as the same, W_2 must equal 2 W_1, since $D_2 = \frac{1}{2} D_1$. Now, if we assume the deflection the same, it is apparent that W_2 must equal 4 W_1; or, the work of deformation is four times as great in the double cantilever beam, strained in one direction, as it is in a circumferential plate, strained in two directions, for equal loads; and this is on the basis that there is no Poisson action, that there is no reduction of strain per unit of stress in one direction by another stress acting at right angles thereto.

Compare a reinforced concrete beam and reinforced concrete plate on posts with square panels, taking an interior panel uniformly loaded, for simplicity, to present the essential facts: The experimentally determined formula for deflection, for the old-style, mushroom, flat plate of concrete, may be written for a square panel as follows:

$$\Delta = \frac{W L^3}{2 \sqrt{2 \times 7\,000\, A_s h^2}} = \frac{W L^3}{19\,800\, A_s h^2} \text{ (approximately).}$$

In this case, L is the diagonal of the panel and Δ is the deflection at the diagonal center. A_s is the steel area at mid-span and h is the distance from the center of the steel to the top of the concrete.

A similar formula, worked out from a number of experiments on thoroughly cured, continuous, concrete beams, integral with the slab, these beams being about 12 in. wide and from 18 to 24 in. deep, with a 6- to 8-in. slab and from 15 to 24 ft. from center to center, is:

$$\Delta = \frac{W L^3}{5\,000\, A_s h^2};$$

in which A_s is the cross-section of the steel at mid-span and h is the distance from the center of the steel to the top of the concrete.

Comparing these formulas, it will be seen that the diagonal deflection of the slab is substantially one-quarter of that of the continuous beam at mid-span, a result in keeping closely with the theory

Mr. Turner. of work above outlined, except that the slab, being integral with the beam, reduces its deflection.

For simple beams, the writer deduced, and published in 1909, a formula in which the coefficient is taken as the reciprocal of 850. Now, the relative stiffness of the continuous and simple beam is known by theory to be as five to one, so that, from these considerations of numerous experimental results, it would appear that the slab integral with the continuous beam has increased its stiffness approximately 18 per cent. The Poisson effect which Eddy finds in his theory is a little greater than this, increasing the stiffness 33 per cent. The simple beams experimented on did not have true knife-edge supports, and this discrepancy would be expected for that reason.

The question, "what is the nature of the Poisson effect in reinforced concrete"?, may be here considered.

Reinforced concrete is not a homogeneous material, but a composite of steel and concrete combined. There can be no molecular action, such as is found in a homogeneous material. The lines of stress, however; may be represented somewhat as are the variations of shade and shadow in a copper half-tone plate. The picture is thrown on the plate through a screen. Shade and shadow are not continuous but are interrupted, and, if the interruptions are sufficiently fine-grained, the appearance to the eye and the general effect is that of the photograph.

So with reinforcement, if we are to imitate homogeneous material, we must have the reinforcement distributed so that the resulting structure is relatively fine-grained. It is on this principle that the imitation of a homogeneous plate may be made. The distribution of the stress and the manner in which the stress in one direction may co-act with that in another has been discussed at length.* The object of this short discussion is to point out the theoretical error involved in the supposition that work, where there is double curvature, is measured largely by the Poisson effect. Poisson effect or action enters into the problem as a relatively minor factor, a matter which Mr. Janni has not discovered, because he has tried to compare beam strips and work through this Poisson coefficient and get at the external work, something which is not possible in working from strips, as the writer pointed out from comparison of the double linear cantilever and the circumferential cantilever.

Much of the difference of opinion among the Engineering Profession to-day regarding beam action and imitation of plate action in concrete may be accounted for through the failure of the Profession generally to understand the theory of work in its relation to horizontal shearing rigidity and flange rigidity.

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* "Concrete-Steel Construction", by Eddy and Turner.

If we have two planks, for example, placed one upon the other, and load them, the stiffness and strength is substantially the aggregate of the two planks, because the friction between them would ordinarily be very small, and the upper corner of the lower plank would slide by the lower corner of the upper plank, if they were of the same length. Now, by bolting and gluing these planks rigidly together, we increase the stiffness fourfold and the strength twofold, because we prevent this sliding one upon the other. The result produced by the resistance of this shearing rigidity at the neutral plane of the beam or slab becomes apparent. Mr. Turner.

If we test a slab which, though hard on the outside is not thoroughly cured at the neutral plane, there is no proportionality at all between the flange stresses and the deflection. If, however, we allow the slab to become thoroughly cured, and compare work which is thoroughly hardened and rigid throughout, then, under these circumstances, we find the most gratifying concordance between relative deflections and stresses.

Initial loading, however, involves some allowance for the shrinkage and temperature stress of hardening. If we are to measure stresses in the concrete of slabs and beams when first loaded, even though they are thoroughly cured, the deformations in the concrete compared should be those of the recovery after the initial loading, and not the initial deformation which includes the effect of the load plus that of temperature and shrinkage stresses in hardening. In subsequent loadings, or after one or two repeated loadings, almost perfect elasticity will be found, but the effect of shrinkage and temperature stresses is more local than general in the slab, and the deflections and steel stresses can be computed accurately with ordinary concrete executed with ordinary care when the work is thoroughly cured and hardened.

Much conscientious hard work in investigating concrete is of no value whatever, because investigators have failed to appreciate the fact that cured concrete is the only kind on which it is worth while to make measurements, because it is the only kind of concrete in which there is a definite relation between the deflection and the amount of load, and consequently the only kind to which mathematical theory of any kind is applicable. Just as sure as concrete is only partly cured along the neutral plane, although hard on the outside, there is no relation between deflection and stress which we have any theory capable of computing, and our measurements then are of no value except in showing what may occur in a slab at this exact stage of hardening, and to duplicate this stage or know that two concrete specimens have reached exactly the same stage of partial curing is something no one has been able to do as yet; hence the measurements made are of academic value only.

Mr. Turner.

Another matter which is very puzzling to many is the fact that the mechanics of a solid is such that ordinary rules of statics do not apply, that is, the rules of statics as applied to the separate members of framed structures are not here applicable. For example, under pure statics, a force in one direction cannot affect the magnitude of the force at right angles thereto. In other words, it has no component which affects it according to statics; but, in the mechanics of a solid, that is not the case. A deformation in one direction under a given force affects and influences the deformation produced by a force at right angles thereto, and it may thus reduce the work done by the external forces to the surprising amount of 80 per cent.

Failure to understand these elementary relations has caused many building departments to adopt irrational regulations, thereby placing a premium on more dangerous types of construction and putting at a disadvantage the more rational and safer types of design.

The difference between beam resistance and slab resistance is, in part, that in the beam horizontal shearing stresses act only in horizontal planes, but in the slab, with its double change in curvature, horizontal shearing forces act in vertical planes as well. Now, the action of these latter forces is disregarded in any beam strip theory, a fact recognized in the classical theory of plates for fifty years. Early flat-plate theories did not take into consideration the Poisson effect at all, a fact which Mr. Janni and many present-day engineers apparently have overlooked.

Mr. Janni assumes that putting an arbitrary factor involving Poisson's ratio into a beam formula makes it apply to a plate. The magnitude of this error may be found by computing the deflection by his theory and comparing the computed values with the experimentally determined deflection.

Working on the basis of beam theory in the design of flat slabs, the quantity of steel used frequently overbalances the strength of the concrete, and unsatisfactory work frequently results. The comprehensive theory, which takes into consideration properly the double curvature and twisting of the plate, whether it is supported on four sides or on a series of posts, will insure the avoidance of this undesirable kind of design. The idea that the Poisson effect in a reinforced concrete slab is a property either of the concrete or of the steel is erroneous. The mathematical coefficient applies to true molecular phenomena. The imitation of that phenomenon in a fine-grained composite structure has no direct relation to a plate, either of uniform concrete or of homogeneous steel.

Another error, which it appears to the writer has crept into many discussions, is the idea that Poisson's ratio is a constant. Its value would seem to depend entirely on the shape of the piece tested, and be a constant for the same kind and shape of test piece, but not for different kinds and different shapes. A square bar would give one value;

a wide rectangular bar would give two values under tensile stress; a plain flat plate bent in one direction gives no criterion as to the Poisson effect in a plate bent in two directions under the fundamental equations of stress and strain. Mr. Turner.

The magnitude of the Poisson effect may be readily shown from the fundamental equations of internal stress and strain—Equations (1) and (2)—to be a maximum when $p_1 = p_2$. In other words, it requires equality of stress in the direction of x and y, respectively, for the maximum efficiency. The previous demonstration of the action of the circumferential cantilever plate is based on this equality, for when the forces along x are greater than those along y, circumferential deformations enter into the deflection largely along x. Hence, the Poisson effect, as well as the effect of double curvature, varies between square and rectangular panels according to the law of this variation. This law is found experimentally to indicate that, in a rectangular panel, the length to be considered is not a mean of the two sides, but is that of the longer side, a relation which holds good with panels in which the width is six-tenths of the longer side. The diagonal length from column to column cannot be used in a rectangular panel, and for that reason the empirical formula for deflection published in 1909 by the writer was confined to the use of the direct span from column to column, using the longer side of the rectangular panel.

Regarding the shrinkage of concrete in columns, this, in the writer's judgment, is a matter which should be given more consideration than is usually accorded it. If the column is well tied in, 12 000 lb. per sq. in. on the steel, if it is hard, should be permissible, provided that the column bars are lapped and not butted. Lapping permits an adjustment during the curing stage which is not possible if the bars are butted. Tests show higher values where the longitudinal steel does not abut the face-plate of the testing machine.

No engineer who has loaded a plain concrete plate and witnessed its performance under a drop of temperature of 25° could rationally talk of the evanescent value of the tensile strength of concrete. In practical construction, the splice or joint eliminates this resistance; still, the deflection is increased but little, and the steel stress likewise undergoes little change. This observation and experience indicate the magnitude of the error involved in Mr. Godfrey's conception of the problem.

Mr. Godfrey has stated that "Tests ought to be made by the Federal Government, not by patent owners, interpreted by their hired experts." His contention, however, is fallacious, and this is shown clearly by the fact that the test of the Curran Building, in St. Louis, was conducted by Robert W. Hunt and Company, and that the report of that company cannot be regarded as unworthy of credence simply because it was made by paid experts. Mr. Godfrey should be informed that

Mr. Turner. numerous articles in the technical press indicate the great extent to which deck mushroom floors have been adopted, in bridge work with columns from 30 to 40 ft. in length, and spans from 30 to nearly 50 ft. There are also many descriptions of tests of such floors; for instance, the floors of the Minneapolis Post Office were tested by the Federal Government.

As a result of the writer's observations, he is firmly convinced that in the past many engineers have attributed the increased rigidity of the work to the tensile strength of the concrete, instead of ascribing it to the increase in horizontal shearing rigidity along the neutral plane of the slab due to thorough curing. Satisfactory evidence of the truth of this fact may be readily brought out by testing a slab without reinforcement. The great importance of this shearing rigidity has been illustrated by the example of the two planks where it increases the stiffness fourfold and the strength twofold. Permitting horizontal shearing rigidity to become a factor in vertical planes has likewise a phenomenal effect on the resistance of the plate, an effect which is brought out only by the double curvature.

It may be argued that the concrete matrix binds the steel and furnishes this shearing rigidity to a large extent. The error of this view will be obvious from the consideration of the example of the two planks which do not furnish the shearing rigidity of the bolts or the glue which increase the stiffness fourfold. Neither does the steel by itself nor the concrete by itself furnish the shearing rigidity of the composite structure. The action as a composite structure is due to bond stress, and bond stress is a shearing resistance added to the combination by the steel embedment and the shrinkage of the concrete in hardening about the steel. Thus, where steel is embedded in concrete we are dealing with a new element which has not been given proper consideration by those who fallaciously assume that the effect of the addition of this shearing rigidity is a property of the concrete. Were this a fact, reinforcement would be abandoned. If concrete can furnish three or four times the tensile resistance of the steel, wherein lies the utility of the steel? In order to account for slab phenomena, an explanation based on an unheard of tensile strength of concrete is offered, the absurdity of which becomes apparent only on analyzing the effect of horizontal shearing forces in horizontal planes and horizontal shearing forces in vertical planes. The erroneous idea that a mere Poisson coefficient accounts in fact for the great difference in performance of the slab and beam becomes evident when we reduce this coefficient to zero and find that the work of deformation for the same load is one-fourth as great with the circular cantilever plate as it is with the linear cantilever plate. No more forcible illustration of the action of the horizontal forces in vertical planes can be brought out than this explanation.

No more cogent reason can be offered for abandoning beam strip theory than the concordance of true theory with empirical, experimentally determined and proved, formulas for deflection. Mr. Turner.

Distribution of Stress.—The composite structure not only differs from the homogeneous plate in respect to the difference between it and the infinitesimally fine grain of the make-up of a homogeneous plate, but also differs in the distribution of resistance under the known law of the bond shear or bond stress. The action of these forces is most efficient where the horizontal shearing deformation is a maximum. This occurs toward the end of the cantilever on each side of the line of inflection in the flat slab supported on columns. Thus, there are differences between distribution of stress in the homogeneous plate and the imitation of the homogeneous plate.

The unique application of the mathematical flat-plate theory of Eddy is based on the assumption of an imaginary solid endowed with those imaginary properties which will produce the deflection of the composite plate. By this expedient Eddy succeeds in figuring the vertical geometry of the composite plate under load, that is, the vertical geometry of the imaginary plate which fits or substantially agrees with that of the composite plate. Having determined this geometry, he has determined mathematically the geometry of deformation, and, reducing this geometry of deformation to stress, he is able to compute, with a high degree of precision, steel stresses and deflections in all recorded tests on thoroughly cured concrete plates. Thus, in one and the same theory, Eddy alone has succeeded in deriving equations by which the deflection and steel elongations are admitted by all to be computed in keeping with results of experiment. It seems to the writer that all criticism of Eddy's methods is based on an entire misapprehension of the stages by which they are derived, and a misunderstanding of the theory of work which, in its simplest and most elementary form, the writer has endeavored to present in the foregoing discussion.

Even in the reinforced concrete beam, it is too commonly assumed that there is a much closer analogy to homogeneous material than actually exists. In the reinforced concrete beam, horizontal shears in vertical planes are also to be found which do not exist in the homogeneous beam. Consequently, these shears which in the lower plane cause greater deformations close to the surface of the steel than between the bars, affect the amount of resistance required to hold the external loads in equilibrium at the center. Since it may be shown that the internal work of deformation in view of the bond stress is in part lateral, the energy there stored has a marked effect in reducing the deflection and the work of deformation, all erroneously attributed heretofore to an overestimated or imaginary direct tensile strength of the concrete. When the work of indirect stress is followed out, and a

Mr. Turner. correct theory of the beam is presented, much of the difference of opinion among engineers on reinforced concrete will disappear.

Time Effect.

Rich Concrete.—Concrete grows more rigid with time aside from shrinkage and temperature effects, but 90-day concrete of a 1:2:4 mix cured at a temperature greater than 65° shows little increase in deformation where the stress is not more than one-third of the ultimate. For greater stresses it shows a considerable and gradual increase in deformation with continuance of pressure, up to a certain limit, which must be considered in the correct interpretation of test results.

Lean Concrete.—In discussing time effects which occur during the curing of concrete, the properties of a standard 1:2:4, or rich, concrete should not be confused with those of a poorer concrete. In cases where, through ignorance or otherwise, buildings have been erected in which a concrete has been used consisting of a 1 cement to 6 bank run of gravel, when such a mix was no better than 1 cement to 5 sand, the quantity of cement is insufficient to fill the voids, and the concrete is not solid. Its physical properties are then very different from that of a standard 1:2:4 mix. Such concrete will continue to deform with time to a surprising extent, without showing many noticeable cracks, and the process of sagging will continue apparently without definite limit for a period of several years. It is evident that such concrete should be avoided as wholly unfit for building purposes, as its characteristics are entirely different from those exhibited by a suitable mix, with which it should not be confused.

Mr. Eddy. Henry T. Eddy,* Esq. (by letter).†—*1.—Fundamental Equations.*—In case the rectangular axes of x and y lie in the horizontal neutral plane, and z denotes the deflection of a flat slab or plate, it is known that the correct moment equations, are‡

$$\left.\begin{aligned}(1-K^2)\,M_1 &= \pm\, E\,I\left(\frac{d^2 z}{d\,x^2}+K\,\frac{d^2\,z}{d\,y^2}\right)\\(1-K^2)\,M_2 &= \pm\, E\,I\left(\frac{d^2 z}{d\,y^2}+K\,\frac{d^2\,z}{d\,x^2}\right)\end{aligned}\right\}\quad\ldots\ldots\ldots(1)$$

in which, for convenience, K is used to express Poisson's ratio of lateral deformation, in place of the expression $\frac{1}{m}$, used by Mr. Janni, M_1 and M_2 are the apparent bending moments per unit of width of slab due to the applied forces or loads which tend to cause flexure of lines initially straight and drawn on the slab parallel to the axes of x and y, respectively.

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* Minneapolis, Minn.

† Received by the Secretary, June 26th, 1916.

‡ See "Concrete-Steel Construction", Eddy and Turner, Minneapolis, 1914, p. 173.

These equations are substantially the same as those used by Grashof in his classical German treatise on the theory of elasticity and strength (1878), and copied in Lanza's American treatise on applied mechanics, which was used for many years, since about 1885, as a textbook at the Massachusetts Institute of Technology. They have been accepted universally as valid, and have never been disputed by any competent writer. Mr. Eddy.

These equations are established by expressing the conditions for the statical equilibrium of an infinitesimal rectangular element of a plate or slab supporting an element of load and subjected on its vertical sides to vertical shearing stresses, and to the tensions and compressions arising from the bending moments as well as to the horizontal shears due to twisting moments. These comprise all the forces that can possibly act on the element, and the conditions for equilibrium are the sufficient and complete expressions for the exact solution of the problem in hand. Any other attempt less general than this must of necessity be, at most, more or less of a tentative approximation, if indeed it can be designated as any approximation at all. So far as known, no such attempt has had any success in approximating to the actual stresses or deflections shown by tests; and the solution which has been derived from Equations (1) has been found to be in numerical agreement with all published tests and many others as yet not published.

Now, the fundamental equations used by Mr. Janni differ from these in reality only in one point, namely, by suppressing and leaving out the last term of each of them. That this is the fact, however, is not entirely apparent, at first view, because Mr. Janni in his mathematical work has chosen to develop the subject by attempting to modify and apply the equations of Professor Fraenkel for beams, which express the work performed during deflection by an assumed auxiliary force applied at the point where the deflection is measured. It may be readily shown, however, that Fraenkel's equations are equivalent to the ordinary equation of flexure of a beam as quoted by Mr. Godfrey, namely,

$$M = E\,I\,\frac{d^2\,z}{d\,x^2}.$$

When Mr. Janni says it is known that the expression for the work is given by his Equation (2), the writer feels compelled to say that the work in a slab or plate is not known to be expressed correctly by this Equation (2), because it is incompatible with the accepted Equations (1) given by the writer, besides other reasons which will be given later.

The only criticism that Mr. Godfrey makes of Mr. Janni's equations is that they involve such mathematical complications as to

Mr. Eddy. prevent most engineers from being able to judge of their correctness. He, himself, does not suggest that they are incorrect, and he is evidently not aware that they are incompatible with the ordinary equation of flexure which he quotes. His remarks, however, convey the impression that he had understood how they were established; but, since they are in fact not correct, Mr. Godfrey cannot have understood how they were derived mathematically.

It is possible to make this assertion of incompatibility between these equations with certainty, notwithstanding the fact that M in Equation (2) is the apparent moment of that part of the total load which Mr. Janni has arbitrarily taken as acting to produce M, while the M_1 in the writer's Equations (1) is due to the entire load, because Equations (1) enable us to determine the shearing stress per unit of width of the section where the bending moment is M_1, and Mr. Janni's arbitrary distribution of the total loading on each beam strip also determines the shearing stress in that strip. This last differs from that previously mentioned, therefore the systems are incompatible. What Mr. Janni has in effect done by his formulas is this:

First, he has reduced the deflection below that of a separate beam strip by assuming the entire load on the slab to be arbitrarily apportioned between the assumed beam strips, which cross each other at right angles parallel to the edges of the panel. Leaving out of account all question as to how this would agree or disagree with some other assumption—such, for example, as diagonal beam strips—the arbitrary subdivision of the loading between the two sets of strips cannot pretend, of course, to any mathematical accuracy, and would have to give way before any mathematically exact method. There is a much more accurate investigation of this kind of hypothesis due to Danusso and edited by von Bronneck* in German, on concrete slabs with crossed reinforcement, in which the strips have identical deflections at all points of crossing, instead of merely on the center strips, as proposed by Mr. Janni. Since the beam strips of Mr. Janni are not required to have identical deflections at any other points than along the middle strips of the panel, his method is necessarily insufficient to secure accurate results.

Secondly, Mr. Janni further reduces deflections by introducing the factor, $(1 - K^2)$, arbitrarily, so far as appears from anything in the paper. It may very well be the fact that this factor is involved in the correct equations, as it is in fact in the writer's Equations (1), but to attempt to take account of the effect on any given strip of the adjacent parallel strips by the insertion of this factor is entirely unwarranted unless the correctness of the procedure is otherwise established.

* Ernst and Son, Berlin, 1913.

Mr. Eddy.

However, regardless of any question of these two attempted corrections of beam theory to make it apply to the beam strip theory of slabs, Mr. Janni has misunderstood and incorrectly used Fraenkel's equations of work and deflection in several particulars, for, in the first place, his Equation (1) is incorrect, and should read

$$d\,L = \frac{1}{2} D\, d\, F$$

because $d\ L$ is the elementary amount of work performed by the elementary force, $d\ F$, when it is gradually applied with the rest of the external load during the progress of the deflection, D.

Mr. Janni, in his Equation (1), has practically assumed that $d\ F$ is already acting on the beam before the rest of the external load is applied to it, whereas it is in fact a part of that load and subject to the same conditions as any other part of it. This alteration alone would change Mr. Janni's results by 100%, were the rest of the development correct.

There is, however, another error involved in his Equation (2) by which the error in Equation (1) is nullified. This can best be appreciated by first considering the external moment, M:

Let M = the total external moment, including F, as given in Equation (4).

Let $\mathfrak{M}$ = the external moment, excluding F, as given in Equation (7).

Let $\mathfrak{m}$ = the moment of F.

Then $M = \mathfrak{M} + \mathfrak{m}$.

Now, in Equation (2), if we disregard the factor, $(1 - K^2)$, the work, L, should be that performed by F during the gradual application of the total load, but Equation (2) is written incorrectly, for it contains the factor, M^2, where it should have, in place of this, the widely different factor $M\ \mathfrak{m}$.

These errors in Equations (1) and (2) are curiously so related, the one to the other, that Equation (3) is the same as would be obtained were the alterations just pointed out made in Equations (1) and (2).

It appears, therefore, that Mr. Janni did not understand the true import of his Equations (1) and (2). Much confusion would be avoided in this paper were a careful distinction observed between the moments, M and $\mathfrak{M}$, as defined by Equations (4) and (7), since M is used in the paper for either the one or the other.

It follows, also, that Mr. Godfrey did not comprehend this matter any better, although he did not say so.

Furthermore, Mr. Janni has introduced the same two arbitrary reductions into the fundamental stress equation for beams that he had already attempted to introduce into his equations for work and deflec-

Mr. Eddy. tion, for he states that "the general equation of stability given by theory" is

$$f \frac{I}{h} = (1 - K^2) M,$$

in which M is the external moment due to the arbitrary and inaccurately assumed external load on the strip, excluding F, while f is the stress in the steel and h is its distance from the neutral axis. There is, however, no proof of the fact that this equation is given by any known theory, although when $K = 0$, the equation is the correct ordinary equation of the stress, f, due to the applied moment, M.

In view of these two corrections, introduced by Mr. Janni into beam theory in his attempt to make it apply to beam strips, the question should be fully settled by him whether both these corrections are required at one and the same time, or whether he should use only one of them, and, in that case, which one is required. He could, perhaps, settle that question by comparing his results with test data. It is not probable, however, that either or both of these corrections will bring the theory into good agreement with observed results. Unless more secure foundations can be established for Mr. Janni's mathematical superstructure than appear in this paper, no great confidence can be put in the substantial validity and accuracy of his conclusions.

2.—Shrinkage, Time Effects and Variation of the Modulus of Concrete with the Stress, etc.—The conclusions of Mr. Jonson are self-evidently incorrect, because it appears, from his Equations (8) and (9), that f_s and f_c, which he finds to be proportional to m, would vanish in case $m = 0$, a case which he himself admits might occur were the concrete kept wet during the process of curing. These absurd results are due to the fact that his Fig. 3 does not represent correctly the relations under consideration.

These formulas have reference to the theory and design of reinforced concrete beams, a subject which has received more careful theoretical and experimental attention than would be implied from Mr. Jonson's remarks, which also intimate that he does not regard himself as having done more than indicate the path along which a radical revision of the theory now current should proceed, a theory on which many eminent engineers have spent their very best efforts. The failure of his Equations (8) and (9) make it evident that his indications are incorrect.

The writer finds himself unable to agree in ascribing any such controlling effect on the theory of beams to shrinkage as Mr. Jonson thinks occurs.

Recourse is to be had in all such matters to scientific experiment and observation, and the object of any theory is to give a rational

explanation and co-ordination of the observed facts. Perhaps the largest single body of well-ascertained data on reinforced beams is found in Technological Paper No. 2, Bureau of Standards, which reports the tests on 333 beams 8 in. wide, 11 in. deep, 13 ft. long, and 12 ft. span, loaded at the one-third points, and with percentages of reinforcement varying from 0.5 to 2 per cent. The gauge length was 29.25 in. Four different kinds of concrete were used, cinder, gravel, broken limestone, and broken granite. Mr. Eddy.

The one noticeable and unmistakable phenomenon of the last three kinds of beam is shown in the graphs in which the abscissas represent the elongations or stresses in the steel at mid span, and in which the ordinates represent either $\frac{M}{b\,d^2}$, or the load, according to the scale used. All these graphs have a pronounced knee at a unit steel stress of about 5 000 lb., and are in general shape like those found in tension tests of a steel rod at the yield point. The tests of cinder-concrete beams also yield similar results, but lack to some extent the sharply defined definite shapes of those just mentioned. Between unit stresses of 6 000 and 30 000 lb., the graph has practically a uniform slope. The elastic limit of the steel used was from 33 000 to 41 000 lb., and its ultimate strength was between 52 000 and 64 000 lb. The working and test stresses, therefore, lay between 6 000 and 30 000 lb. The important question, therefore, is this: what is it that causes the knee at a unit stress of about 5 000 lb.? The question seems to have been answered in a paper* by Mr. Duff A. Abrams, on "Tests of Bond between Concrete and Steel," in which, besides pull-out tests of embedded rods, Mr. Abrams reports a large number of tests on reinforced beams loaded at the one-third points. He finds (page 207) that:

"* * * bond between concrete and steel may be divided into two principal elements, adhesive resistance and sliding resistance. * * * The adhesive resistance must be overcome before sliding resistance comes into action. In other words, the two elements of bond resistance are not effective at the same time at a given point". (Page 208.) "If we conclude that adhesive resistance was overcome at the first measurable slip, it will be seen that the adhesive resistance was about 60% of the maximum bond resistance. This ratio did not vary much for a wide range of mixes, ages, size of bar, condition of storage, etc. * * * Sliding resistance reached its maximum value for plain bars of ordinary mill surface at a slip of about 0.01 in. The constancy in the amount of slip corresponding to the maximum bond resistance for a wide range of mixes, ages, size of bar, conditions of storages, etc., is a noteworthy feature of the tests. With further slip the sliding resistance decreased slowly at first, then more rapidly, until with a slip of 0.1 in. the bond resistance was about one-half its maximum

* *Bulletin No. 71,* Engineering Experiment Station, University of Illinois, 1913.

Mr. Eddy. value." (Page 216.) "Slip of bar was a phenomenon in all beam tests in which careful slip observations were made. * * * Slip was first observed in the middle region of the span at loads producing a tensile stress in the steel of about 6 000 lb. per sq. in. * * * As the load was increased, slip of bar progressed through the outer thirds toward the ends of the beam at a rate nearly proportional to the increase of load."

Without making further quotations from this important paper, it is clear that any initial shrinkage stresses which the concrete may exert on the steel are limited in their action by the bond, so that they have no important effect on the steel after it reaches a unit stress of 6 000 lb., and therefore they need not be considered as having any influence on working stresses after that. The knee of the graph of the steel stresses in beams is evidently reached when the adhesion ends and the slip begins in the central region, which later progresses into the end thirds, this masking any initial shrinkage effect.

In the tests of these simple beams (page 218) "the maximum bond resistance was materially increased by the additional overhang" at the ends of the beams beyond the supports. In continuous beams it is evident that there is no opportunity for the rods to slip at the points of inflection, as they may at the ends of simple beams, and for that reason such beams may be taken as having a very long overhang. Slip in the central portion of a simple beam makes it act more and more like a bowstring girder as the slip progresses toward the ends, while a continuous beam has this tendency checked at the points of inflection. The same thing occurs in a flat slab. The graphs of the reinforcing rods given in the various tests of flat slabs supported on columns exhibit the same phenomenon of a knee as do simple beams, but usually at a much lower unit stress than 6 000 lb.

Apparently, the sharp change of direction of the graph at the so-called knee is a complex result dependent both on shrinkage and slip, which are related to each other in flat slabs somewhat otherwise than in beams, for this reason, if for no other, that such slabs have a depth not much more than half as great as beams of equal span, and the shrinkage grip of the concrete acts somewhat differently on crossed rods than on parallel rods. These, in some way, apparently, bring it about that the shrinkage stresses in the steel in flat slabs disappear at much lower steel stresses than in beams, and the slip is restricted to a small area at and around the column caps, so that the deflections due to this cause in the case of beams is very greatly reduced in the case of flat slabs.

The fact that the graph in beams is practically straight within the range of the working and test unit stresses from 16 000 to 30 000 lb., and that the neutral axis usually varies by much less than 10% of the depth on either side of the mid-depth, and, further, that the

center of compression remains practically fixed in the beam for considerable variations of n, the ratio of the steel and concrete moduli, seem to destroy the cogency of Mr. Jonson's objections to the treatment of reinforced concrete on the basis of a suitably modified elastic theory. Mr. Eddy.

It is slabs, however, rather than beams, which should claim our principal attention in this discussion. It appears that the most significant phenomenon exhibited by a panel supported at its edges by walls, or relatively stiff beams, is one which has been overlooked in the discussion thus far, a phenomenon which is exhibited by both slabs and plates in common. The experiments of Bach on plates supported in this manner showed that the failure of such plates was caused by their cracking along valley lines starting from each corner of the panel and almost exactly bisecting the corner angles, regardless of the square or oblong dimensions of the panel.

It is not difficult to imagine how this would occur, for, assume the plate to be supported, to begin with, on corner posts only, and after it has been deflected and has bent downward under the loading, that it be gradually lifted by screw-jacks which raise stiff beams under the edges of the panel. In this way it is evident, at any time when the deflection of a side has been partly removed, that there is a sudden change of curvature which approaches discontinuity between the part of the slab that has been lifted on the beam and that part not yet lifted. Such a valley line, by reason of the comparatively sharp curvature across it, would be a line of great stress. Now, the analysis which has been proposed does not deal with this phenomenon at all, although it is the one thing of primary importance. The writer has attempted to treat this matter in the book previously referred to, and he knows of no other attempt at a theory of it. The attempted theory is shown to be in good accord with all available tests. Any theory which ignores, as does the present theory, this the most noteworthy experimental phenomenon of a thin slab with relatively stiff supports at the edges of the panels, cannot command our confidence, at least until it can be shown that it is in accord with experimental results such as seem to be totally lacking in this development.

3.—Ratio of Lateral Distortion in Deformed Slabs and Plates.— The ratio of lateral distortion designated by K or by $\frac{1}{m}$ in the foregoing theory, which has been called Poisson's ratio, is in fact something very different from what is ordinarily designated by that phrase, and should no longer be called by that name. Poisson's ratio is the relative amount of the lateral compared with the longitudinal distortion, when a piece of material such

Mr. Eddy. as a flat plate or rod is elongated or shortened by direct stress. What occurs in the steel when a reinforced slab is subjected to bending is something quite different from the stretching of a flat plate, and is much more nearly analogous to the bending of a plate which has been stamped with a die into a pattern with alternate hills and valleys or dome-shaped convexities and saucer-shaped concavities, since that is the shape of the enclosed steel mat inside of a flat slab, a mat which, by reason of its embedment of interlocking concrete and its high comparative rigidity, acts not like a flat plate, but instead like a deformed continuous sheet of steel composed of many elevations and depressions. In order to form a correct idea of the deformation of such a sheet on bending, imagine a single saucer-shaped concave plate to be somewhat bent about a diametral line. One diameter of the saucer becomes less while that at right angles becomes greater. The radius of curvature of the normal section containing the smaller diameter thus becomes smaller while the radius of the other section becomes greater. The necessary connection and relation of these changes of curvature and the accompanying compressions and elongations on the surfaces of the plate have nothing whatever to do with the molecular phenomenon which controls Poisson's ratio, but are due to the geometry of curved surfaces although they might be modified somewhat by the magnitude of Poisson's ratio for the particular materials of which the curved plate is composed.

It is evident that, for a plate forming a segment taken from a hollow sphere of incompressible material, the distortion due to bending it would be such as to make the lateral and longitudinal distortions approximately equal. Thus K would be nearly equal to unity for such a substance, no matter how small Poisson's ratio might be; but, in such a plate, formed of some compressible material, K would be smaller. Its actual value would be a matter of experiment. It is this ratio of distortion of deformed plates that is contained in Equations (1), and not Poisson's ratio proper. The latter plays a very subordinate rôle in this theory, and the actual value of this ratio for the kind of material used has little or no relation to the value of K that must be used in these equations. It may be noted further that, in addition to the curvatures of the steel in the slab, the slab itself is likely, under its own weight and as an after effect of loading, to have some small deformations of a kind similar to those due to the curvatures of the steel mat.

The steel mat, in a flat slab on columns, however, does not consist entirely of convex and concave areas, for between these lie areas of twisted curvature which occupy approximately half of the total area of the slab. The mean value of K in Equations (1) depends in almost equal degree on these areas of saddle-shaped curvature and on those that are convex or concave. So far as the concurrent evi-

dence of tests go, the mean value of K for flat slabs supported on columns with the ordinary arrangement of steel is $K = 0.5$, although the value of Poisson's ratio for concrete alone certainly is not half as large as that. The manner in which K affects the deflections and resisting stresses of the steel is by the reduction factor, $(1 - K^2)$, and its influence, consequently, is much less than is often tacitly assumed by those who reason about it, as may be seen from the following tabulation: Mr. Eddy.

$$K = 0.1 \quad 0.2 \quad 0.3 \quad 0.4 \quad 0.5$$
$$1 - K^2 = 0.99,\ 0.96,\ 0.91,\ 0.94,\ 0.75$$

from which it appears that, for values of K less than 0.2, its effect may be disregarded, but for $K = 0.5$, the effect modifies the values obtained by disregarding K by 25% at most.

So far as is known, this is the first time that it has been pointed out that the value, K, which must be used in equations of flat plates, is to be determined principally by considerations other than the molecular properties of the particular materials of which the plate is composed, a fact which obviates the many criticisms which have been passed on any theory using any value larger than that found for the material of the plate. Those criticisms have assumed that, without question, the true value of Poisson's ratio for the materials composing the plate must of necessity be used in Equations (1), which is not the fact.

The tests that have been made of flat slabs on columns have shown that, when the steel runs in belts over the columns, the stresses are almost entirely limited to the panels which carry the loads, and little effect is propagated from panel to panel. This has been thought by some to be due entirely to the stiffness of the supporting columns, as it undoubtedly is in part; but the foregoing discussion reveals an additional reason why the stresses in a panel are self-contained, much as it would be were it an arched or bow-string girder construction running to the columns. Such, however, is not the case to such a marked extent with two-way reinforcement in which rods cross the sides of the panels at mid-span and propagate moments more readily from panel to panel.

In the first of these constructions there are only comparatively small movements of the lines of inflection when a single tier of panels across a floor is subjected to a test load, and the action is not the same as it would be in a wide beam, because the action is more or less like attempting to collapse or flatten out a corrugated pipe instead of a plain pipe. It brings out the resistance of the reinforcement in a different and more effective manner.

It must be remembered that the actual statical moments of given loads in any panel cannot be altered by any process. The only ques-

Mr. Eddy. tion is how these moments are subdivided and resisted by the reinforcement. Other things being equal, that certainly occurs most economically when each panel is influenced least by adjacent panels, and at the same time each panel assists its surrounding panels as much as possible. In the case of a slab supported on relatively stiff beams or walls, each panel is largely independent of surrounding panels, and the lines of inflection lie relatively near the beams. The relative flexibility of the the slab is so large, and the deflection of the beams which support it is relatively so small, that the effect of their deflection is less important than seems to be imagined by Messrs. Janni and Jonson, and is negligible compared with the other inaccuracies of the method.

Mr. Mensch. L. J. MENSCH,* M. AM. SOC. C. E. (by letter).†—The author's assumption for the distribution of loading of the central strips of a rectangular slab is probably not far out of the way; yet his theory is misleading, because it is as little proper to assume that the average bending moment for such a slab should be figured as the moment of the central strips as it would be to assume that the eye-bar of a pin-connected bridge is strained only for a width equal to the diameter of the pin. During the last 12 years many investigators have divided rectangular slabs into a number of strips, thereby obtaining a clearer view of the behavior of the slabs. Danusso went further,‡ and investigated the influence of the diagonal strips which connect the center of the supporting girders and others parallel to them and nearer to the corners, and found that they greatly relieve the central strips. According to his theory, the average bending moment for a square slab freely supported on four sides is about $\frac{w\,l^2}{30}$, and, for one fixed on four sides, the average bending moment is about $\frac{w\,l^2}{70}$ in the center of the span and $\frac{w\,l^2}{34}$ at the supports. This seems to agree with nearly all recorded tests on such slabs.

Very instructive tests were made on two slabs of the "Palais de Costume" at the Paris World's Fair in 1902. One slab was about 22 ft. square, 6 in. thick, reinforced by ⅝-in. round bars about 6½ in. from center to center, and supported by light girders on very light columns. At a total load of about 500 lb. per sq. ft. the girders and columns were at the point of failure, and the girders had to be supported by temporary props and the test discontinued. The slab itself did not show any sign of very near failure, indicating that

* Chicago, Ill.

† Received by the Secretary, July 20th, 1916.

‡ *Il Cemento*, 1912.

the negative bending moments produced great torsional stresses in the narrow girders and dangerous eccentric loadings in the light columns at a stage of loading which was probably only two-thirds of the ultimate carrying capacity of the slab. Better results were obtained with another slab, about 21 by 24.5 ft., supported on girders 18 in. wide and 24 in. deep, which girders were of considerably greater span than the slab proper. In this case, also, the girders failed first, which happened at a loading corresponding to an average bending moment in the slab of $\frac{w\,l^2}{38}$. The slab itself did not show any very near approach to failure. Mr. Mensch.

We can cite also the very thorough tests made by Professor Bach, in 1914, on square and rectangular slabs simply supported on four sides. For comparison, Professor Bach tested also beams simply supported on both ends, having the same depth and the same percentage of reinforcement as the slabs. The diagonal strips (although the reinforcement ran only in two directions) were carrying a great part of the load on the slab, as was shown by the direction of the cracks on the underside of the slab, and the average moment at the ultimate load was found to be about $\frac{w\,l^2}{28}$. The tests on rectangular slabs, with side ratios of $1:1\frac{1}{2}$ and $1:2$, and with the same percentage of reinforcement in both directions, gave the remarkable result that the ultimate load per square foot was from 77 to 85% of that obtained for a square slab the length of the sides of which was equal to the smaller side of the rectangular slabs. This can only be explained by the very pronounced action of the diagonal strips and by the fact that the limit of elasticity is first reached in the short direction, producing comparatively large deflections, thus allowing the longer span to take up the remainder of the load.

The writer heartily agrees with Mr. Jonson that the theory of reinforced concrete, as found in nearly all textbooks, ordinances, and in the reports of the Joint Committee, is rather crude, and should be entirely discarded. The theory is wrong because the plane-section theory and Hooke's law do not apply to reinforced concrete, even at ordinary loads—a fact proved by Professor Schule 14 years ago—and, as may be expected, is far from the truth at ultimate loads. Because we encounter very great difficulties in investigating the properties of any material near rupture, making it practically impossible to measure the flow or plasticity of the materials, the great mathematicians of about 100 years ago developed theories for the strength of materials based on stresses below the elastic limit, which, although they were a great improvement over the guess methods previously used, do not lead to constructions having the same factor

Mr. Mensch. of safety in every part. Following faithfully their lead, we were taught to allow stresses of about one-fourth of the ultimate strength of the materials, and have trusted ever since to good luck that our structures, designed according to these rules, have a factor of safety of about 4.

During the last 30 years a great number of testing laboratories have been erected in various parts of the world, and we now have more information about the strength of structures than ever before. Very slowly the fact has been brought out that our theories do not explain the ultimate strength of many members of constructions, and that it is advisable to use different working stresses for such members. This Society has recently helped to make most thorough tests on structural steel columns. No theory, according to the old standards, seems to fit these tests, but, if we take into consideration the properties of steel at the time of failure, especially the fact that the modulus of elasticity near rupture is considerably less than the initial value of 29 000 000 lb. per sq. in., on account of the flow of the material, and if we introduce the correct value of E in Euler's formula, we readily obtain a good agreement between theory and test. Of course, where $\frac{l}{r}$ is large, the ultimate unit stress is below the elastic limit, and in this case E equals 29 000 000, and for such long columns Euler's formula always gave satisfactory results. Similar discrepancies in old established theories were lately found also for rolled I-sections in bending, and there is no doubt that tees, angles, and other unsymmetrical sections will show still greater variations. If such is the case with a homogeneous material like steel, we may question in a still greater degree all reinforced concrete theories which are based on Hooke's law and the plane-section theory.

The writer has shown* that neither the plane-section theory nor Hooke's law is required to explain the results of tests on reinforced concrete girder and slab construction which failed without bond or diagonal tension failure.

Fig. 4 represents the ideal stress distribution in a section of a beam at the time of failure. Let f_c = the ultimate strength of concrete in pounds per square inch, as shown in cylinder tests. Let f_s = the ultimate strength of reinforcing steel in reinforced concrete construction, which experience shows is about a mean between the elastic limit and ultimate strength, and all other notations as given by the Joint Committee, then, from the necessary condition that total compression equals tension, we have

$$\frac{2}{3} b\ k\ d\ f_c = p\ b\ d\ f_s$$

* *Journal*, Am. Concrete Institute, December, 1914.

Mr. Mensch.

$$k = 1.5 \frac{f_s}{f_c} p$$

$$M = p\, b\, d\, f_s \left(d - \frac{3}{8}\, k\, d\right) = p\, b\, d^2\, f_s \left(1 - \frac{3}{8}\, k\right)$$

or $$\frac{M}{b\, d^2} = p\, f_s \left(1 - \frac{3}{8}\, k\right)$$

or $$M = A_s\, f_s\, j\, d, \text{ when } j = \left(1 - \frac{3}{8}\, k\right).$$

The writer has shown (in the paper mentioned) that by assuming $f_s = 45\,000$ lb. per sq. in. for mild steel, 72 000 lb. for high-carbon steel, and 110 000 lb. for commercial high-carbon drawn-steel wire, the ultimate moments, according to this formula, agree, within a small percentage, with the ultimate moments of nearly all published

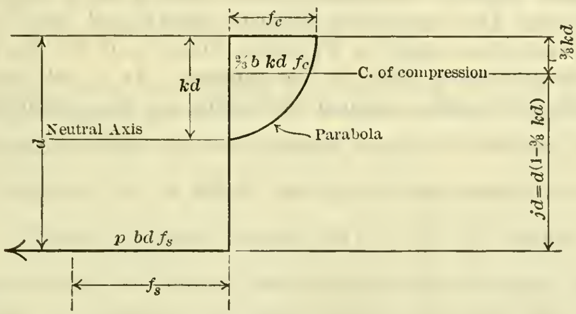

FIG. 4.

scientific tests on beams which he could find. Hence, the value of n is of no account in the investigation of the strength of a beam. In regard to its probable value at the ultimate load, it is known that the steel reinforcement in nearly all tests first shows signs of failure before the concrete is highly strained in compression, which means that the steel reaches and exceeds the elastic limit long before the concrete attains it in compression; when the steel exceeds the elastic limit, E drops very suddenly, and its probable value, just before rupture of a reinforced concrete beam, is less than 1 000 000 lb. per sq. in. The concrete in compression is not as plastic as steel, and it is probable that its modulus of elasticity near rupture is not less than from 300 000 to 500 000 lb. per sq. in., or the probable value of n at the ultimate load $= \dfrac{1\,000\,000}{500\,000} = 2$, and not—as Mr. Jonson states—30 or 40. Mr. Jonson's statement that "all calculations of reinforced concrete made on the assumption that the ratio, n or E divided by E_c, is a constant are unreliable * * *" shows that he is not familiar with the literature on reinforced concrete or statically indeterminate structures. Except for the influence of temperature

Mr. Mensch. variation and shrinkage, the stresses in statically indeterminate structures never depend on the absolute values of $E\ I$, but on a function of the ratio of the value of $E\ I$ at any particular point, x, to a fixed value of $E\ I$ at any important point. Where $E\ I$ is constant, the moment of inertia has no influence whatsoever on the stresses caused by the indeterminate values, and, where I varies, the stresses depend generally on a function of the ratio of $\frac{d^3}{d_x^3}$ for rectangular sections. Assuming even that the moment of inertia is not proportionate to the 3d power of the depths of the section, the mistake appears only in a function of the ratio, and is of small influence; a mistake of 100% in the moment of inertia causes often a change in the stresses of only a few per cent.

Professor Morsch investigated this subject about 8 years ago and found a very fair agreement between theory and practice. More scientific tests were made by Professor Scheit and Mr. E. Probst on continuous girders on three to five supports. It is well known that, in a girder of constant moment of inertia, on three equidistant supports, the statically unknown moment over the central support is $\frac{W\,l}{8}$. Their tests showed that the girder failed at the moment over the central support of $\frac{W\,l}{10}$. The actual bending moment is smaller than that given by the elastic theory, which is easily explained by the fact that the elastic limit over the supports is reached long before the center of the spans is strained to the elastic limit, which has an effect of equalizing the moments over the supports and in the center of the span. These investigators obtained similar results for girders on four and five supports and for framed structures.

The influence of shrinkage of concrete on the strength of reinforced concrete beams is not solved yet, but is being thoroughly investigated at present by the United States Bureau of Standards. The tests made by Richard L. Humphrey,* M. Am. Soc. C. E., show that beams 1 year old were always stronger than those 4, 13, or 26 weeks old; which does not indicate that shrinkage unfavorably affects beams 13 ft. long reinforced with from 0.5 to 2% of steel.

Mr. Marsh. CHARLES F. MARSH,† M. AM. SOC. C. E. (by letter).‡—The coefficients commonly used in Great Britain, for obtaining the proportions of the bending moment acting transversely and longitudinally in slabs supported on four sides, are obtained from the formulas of Grashof and Rankine, or those recommended by the French Government Commission on Reinforced Concrete.

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* *Technologic Paper No. 2*, Bureau of Standards.

† London, England.

‡ Received by the Secretary, July 19th, 1916.

Mr. Marsh.

An inspection of the values given by these formulas will show that in both cases the transverse coefficient approaches unity as the ratio, $\frac{l_1}{l}$, increases, but never reaches this value; and the longitudinal coefficient approaches but never reaches zero as the ratio, $\frac{l_1}{l}$, increases. and, from the nature of the case, these would appear rational and obvious results.

By the use of Mr. Janni's formulas, the transverse coefficient is unity and the longitudinal coefficient is zero when $\frac{l_1}{l} = \frac{5}{3}$, and their use for ratios of $\frac{l_1}{l}$ greater than $\frac{5}{3}$ gives a transverse coefficient greater than unity and a minus quantity for the longitudinal coefficient. Such results do not impress one as being in accordance with the facts.

Mr. Janni obtains his formulas by considering the slab as divided into systems of beams parallel to the short and long sides of the slab and equating their deflections at the center; the formulas of Grashof and Rankine are obtained by the same method.

The introduction of the effect of Poisson's coefficient is doubtless essential, from an academic point of view, but the practical utility and accuracy of the results are of doubtful value, especially when, as a preliminary, the important assumption is made that the moment at P is reduced to two-thirds of its theoretic value by reason of the doubtfulness as to the efficiency of the fixation.

With respect to Mr. Jonson's discussion, it might be well to point out that the generally accepted methods of treatment, working stresses, and coefficients were recommended by the various authorities after full consideration and knowledge of the general effect of the various influences other than those actually provided for in the formulas, and there appears to be no reason to doubt that structures designed by the use of such formulas and the stresses and coefficients recommended will, if properly constructed, be amply sufficient to serve the purposes for which they are designed.

The initial strains due to the shrinkage of the concrete when setting do without doubt have an effect on the structure, but other conditions also affect the resistance, such as loading and unloading, temperature and humidity, the greater facility of the reinforcements than of the concrete in recovering after straining, etc.

In any case, it is very doubtful whether Mr. Jonson's conclusions with respect to the effect of the initial strains due to shrinkage are correct, and it is more than probable that these strains would add to the resistance of a reinforced concrete member.

Mr. Marsh.

Shrinkage of the concrete induces compressive stress in the reinforcements and tensile stress in the concrete and, in the case of a member subjected to flexure, if the concrete does not crack on the compression side of the neutral axis, the resistance of the member is increased; but if the concrete cracks, as the initial stresses are induced before the cracking occurs and the crack must close up before the concrete can be stressed by the loading, the initial strain of the reinforcement must be removed, leaving matters as they were before the shrinkage.

In the case of a member under direct compression, the initial compressive stress on the steel added to the compressive stress due to loading will never approach the permissible working stress on the steel.

From the results of published experiments it would appear that the value of Em for 1:2:4 concrete is not likely to have a range greater than from — 3 000 when the setting takes place in water to + 6 000 when the setting takes place in air.

With respect to the value of the coefficient, n, it is well known and recognized that its value may vary between wide limits, and that the value used in calculations must necessarily be in a great measure hypothetical.

Many experiments have been made with the object of ascertaining a proper value for this coefficient, and the results have varied considerably, which is hardly surprising, considering the nature of the material under test.

Mr. Jonson concludes, from certain recently conducted experiments, that the modulus of elasticity of concrete decreases with age, whereas similar experiments in the past have indicated an increase. From a careful study of experiments bearing on the value of this modulus conducted up to about 1908, it was concluded that a fair average value was about 1 740 000 under a stress of 600 lb. per sq. in., giving n a value of about $17\frac{1}{2}$, but that the tendency of the concrete to take a permanent set, while the steel was truly elastic, would have an effect equivalent to a decrease in the value of n, and, consequently, it was concluded that the adoption of a value of 15 for n was a reasonable assumption. It was also found that the results of actual experiments on reinforced concrete beams justified this value.

The treatment of continuous construction as consisting of a series of cantilevers supporting beams at their ends is a method which is frequently adopted, but its accuracy is questionable, especially where the loading may vary and the spans are unequal.

For the ordinary floor design, it would appear that approximate coefficients for the bending moments, such as those given in the London County Council Regulations, might be used with perfect safety and with a great simplification of the calculations.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

TEMPERATURE STRESSES IN A SERIES OF SPANS

Discussion.*

By Charles W. Martin, Assoc. M. Am. Soc. C. E.

Charles W. Martin,† Assoc. M. Am. Soc. C. E. (by letter).‡—The writer has read this paper with some interest, but, save for a "look in" at the general principles, has made no attempt to follow the theoretical analysis. Mr. Martin.

In the design of reinforced concrete bridges and viaducts for the City of St. Louis, the writer, from time to time, has given considerable thought to the matter of expansion joints and stresses generated by changes of temperature. At the first glance through Mr. Gregg's paper, he was somewhat amazed at the high stress units tabulated for the structure, with the several arrangements of joints and bearings as described.

In a series of spans, temperature changes generate two distinct combinations of forces: bending combined with shear in the piers, and axial forces combined with bending in the deck. The magnitude of these forces varies directly with the moment of inertia of the pier sections in any given system of spans and piers. Thus it happens that, as in the case of the design of flat arch ribs subject to temperature changes, one frequently finds that, to reduce the stresses in the structure, he must make certain parts more flexible. In the design of a series of spans and piers, relief from high temperature stresses is obtained by a reduction of the pier sectioning.

The structure which Mr. Gregg has selected to illustrate his theory has an extremely inflexible arrangement of skewed piers, and

* This discussion (of the paper by Tresham D. Gregg, Assoc. M. Am. Soc. C. E., published in February, 1916, *Proceedings,* but not presented at any meeting) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† St. Louis, Mo.

‡ Received by the Secretary, June 3d, 1916.

Mr. Martin. to this is due, in accordance with his analysis, the unusually high temperature stresses. Here, the characterization "unusually high" is used advisedly, particularly as regards the axial stresses for the spans in his Cases 4 and 6 of Table 1, for if one considered any span absolutely restrained from change in length, the temperature stresses would not greatly exceed those reported.

Although the principle of Mr. Gregg's theory may be quite useful, the writer thinks he was unfortunate in the selection of a trial structure. With a structure in which the piers have such a skew, the critical guess one has to make is as to the direction of the principal distortions. Mr. Gregg has assumed that these act parallel to the longitudinal axis of the structure, whereas actually to do the "least work", these principal distortions will act in some oblique direction which will depend on the skew of the piers and the lateral restraint at the ends of the outmost spans.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DESIGNING AN EARTH DAM HAVING A GRAVEL FOUNDATION, WITH THE RESULTS OBTAINED IN TESTS ON A MODEL

Discussion.*

By Messrs. E. C. La Rue, George M. Bacon, H. A. Petterson, and D. C. Henny.

E. C. La Rue,† Assoc. M. Am. Soc. C. E. (by letter).‡—This paper will be of exceptional interest, for only meager data are available relating to the proper design of an earth dam having a gravel foundation. The partly completed dam, described by Mr. Hays, formed a part of an irrigation project on which the writer has prepared a water supply report. He has also examined the dam site, and is therefore specially interested in the paper. Mr. La Rue.

In some parts of it the author has not made clear the procedure followed in his experimental work. For example, in determining the hydraulic gradient of the material used in the original dam and that to be used in the upper portion of the actual structure, the details of the methods are not made clear. The writer is in doubt as to the following points:

1.—When the readings were taken, was the quantity of water leaving the same as that entering the tank?

2.—Before the soil was placed in the tank, were tests made in order to determine the head required to force the water through the valve? If the coarse materials were tested to determine the hydraulic gradient, then, with the same quantity of water flowing into the empty tank

* Discussion of the paper by James B. Hays, Jun. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† Salt Lake City, Utah.

‡ Received by the Secretary, May 8th, 1916.

Mr. La Rue. as that used in the test, the head required to force this water through the valve could be determined. If, during such tests, it was found that the water level in the tank was above the intake to the lower glass tube, then the author's results are in error. During the tests, with the soil in the tank, the head required to force the water through the valve would be effective to a higher level in the tank. It is probable that the water level in the lower tube was not affected in the manner referred to, but the author has not made this point clear.

On page 323,* in referring to the North Dike of the Wachusett Dam, Mr. Hays states:

"A flat hydraulic gradient, caused by the water in the reservoir seeping under the dam, called for a large quantity of material, in order to withstand the upward pressure under the down-stream portion of the dam."

In referring to the Gatun Dam, he states:

"A flat down-stream slope causes the percolating water to travel a long distance before a free opening is encountered, thus causing the upward pressure to be consumed by friction."

As the down-stream sections of these dams are constructed of pervious material, the water cannot exert an upward pressure on their bases. Probably the author means that the flat hydraulic gradient makes it necessary to construct the down-stream section of the dam with a flat slope in order to prevent the line of saturation from intersecting the down-stream face of the dam above the toe.

On page 333,* in referring to the hydraulic gradient for the selected material to be used in the upper section of the actual structure, the author says: "From this it was assumed that the hydraulic gradient was not greater than 1:1, although it was evidently much steeper." This statement is not consistent. It would appear that he meant to say that the hydraulic gradient was not less than 1:1, and it was evidently much steeper.

On page 333,* in referring to the model dam, the author says:

"The long up-stream slope was given in order to allow the downward pressure of the water over the up-stream section to have a balancing effect on the upward pressure beneath the dam, as blow-outs would be improbable in this portion of the dam."

Although the down-stream pressure of the water over the up-stream section does have a balancing effect on the upward pressure beneath the dam, this surely was not the reason for adopting a "long up-stream slope". The author assumes that the material in the up-stream section will be practically water-tight. It would appear, therefore, that the

* *Proceedings*, Am. Soc. C. E., for March, 1916.

flat up-stream slope was adopted in order to force the hydraulic gradient to begin farther up stream. Mr. La Rue.

The author concludes that, with 10 in. of water in the reservoir above the model dam, the head is entirely consumed before the water reaches the lower toe of the dam. Using Test No. 17, Table 3, the writer has drawn lines of equal pressure, and from these produced the lines representing approximately the direction of flow through the foundation of the model dam. The direction of flow was downward in that portion of the foundation above the sheet-piling. Below the sheet-piling the flow lines rose slightly and then appeared to turn in the direction of the drain valve, shown in Fig. 8. If the pressure had been observed at various points in the foundation below the lower toe, there is no doubt that it would have shown conclusively that the direction of flow was toward the drain valve. Mr. Hays has shown the hydraulic gradient for the material used in the foundation to be about 1: 9. With a free escape for the water, as is provided by the drain, little, if any, pressure would be observed immediately above the drain valve. Extending the hydraulic gradient back from the drain valve with a slope of 1: 9, it will be seen to intersect the line representing the base of the dam at a point 2 160 ft. above the drain, or 1 040 ft. up stream from the upper toe of the actual dam. All the pressure observations taken by the author must have been affected by the drain. Under these conditions, the water could not rise to the base of the dam near the lower toe. In the model, the author has imposed conditions which would not be reproduced in actual practice. If the dam is to operate under the same conditions as the model, then 360 ft. below the lower toe of the dam a trench, 240 ft. deep and 40 ft. wide, must be constructed across the canyon. This trench must be filled with large stone, in order to provide a perfect drain. In the bottom of the trench, or at the 240-ft. level, there must be openings with sufficient capacity to carry off the water as it arrives. The water must then be conveyed to a reservoir of infinite capacity. In the model, the drain should be 216 in. from the lower toe, instead of 36 in., or it will affect the water pressure under the base of the dam. If the writer's contentions are correct, the results of the author's experiments are of little practical value.

That the drain referred to has affected seriously the results of the experiments is indicated by the excessive seepage through the foundation of the model. In Test No. 17, Table 3, the seepage, per linear foot of the model, was 0.00222 cu. ft. per sec. The slope of the line of saturation in the model is assumed to be the same as that of the actual dam. The length of travel in the model is proportional to that of the actual dam. The head and all other dimensions in the model being proportional to those of the actual dam, the seepage through the latter, per linear foot, will be 120 times that through the model per linear

Mr. La Rue.

foot. The length of the actual dam is to be 2 000 ft., and its left end will extend into a bank of gravel similar to that which is to compose the foundation. Considerable excavation will be necessary in order that the water-tight section of the dam can be carried well into this bank. It is assumed that the area exposed to water pressure will be equivalent to the area of 1 200 ft. of maximum section. The seepage through the actual dam, therefore, would be $120 \times 1\,200 \times 0.00222$, which equals 320 cu. ft. per sec.

Mr. Hays has not disproved the "line of creep" theory. In the first test, with the two rows of sheet-piling, he found a small loss of head at the upper row of piling. This, no doubt, was due to water passing through the upper section of the dam and entering the foundation both above and below the upper row of sheet-piling.

The pressure at *D,* Fig. 8, below the lower row of sheet-piling, was no doubt due to the water from the upper section of the dam entering the foundation between the piling and the cut-off wall. In fact, the drain would prevent the water from rising to *D* after passing below the lower row of sheet-piling. If Mr. Hays will place the drain 216 in. below the lower toe of the model dam, separate the upper section of the dam from the foundation, with a sheet of tin, and connect the tin with the cut-off wall and the two rows of sheet-piling with water-tight joints, then the hydraulic gradient will begin at the upper toe. Under these conditions, the effect of the two rows of sheet-piling can be determined, and undoubtedly the "line of creep" theory, somewhat modified, will prove to be correct. That is, instead of following down one side of the sheet-piling and up the other, thence along the base of the dam to the second row of sheet-piling, etc., the water will follow down the upper side of the first row of sheet-piling and thence in the general direction of the lower end of the second row of sheet-piling.

Assuming that there were no other defects in the model, the writer believes the results of the tests to be unreliable for the following reasons:

1.—The model dam, being only 11 in. high, and subjected to a head of 10 in. of water, the entrance head and capillary action would, no doubt, affect the hydraulic gradient to such an extent that the pressure observations in the model would not indicate the action of the water in the final structure, where similar material will be subjected to a head 120 times greater than that on the model.

2.—The model dam was constructed of the same material as that to be used in the actual structure. It would seem that the material for the former should have been coarser than that to be used in the latter. The ratio between the coarseness of the materials in the two structures, which would result in the action of the water on the model being comparable to that on the actual dam, could perhaps be determined by extensive experiments.

The writer makes the following suggestions: Mr La Rue.

1.—That the author construct a model which will represent exactly the original dam as it was to have been built. It is probable that the results of tests on this model would show the structure to be safe, provided the model were constructed with the drain 36 in. below the lower toe. As a matter of fact, with a head of 24 ft. on the actual dam, the water passed freely through the partly completed structure.

2.—That the author could obtain more reliable information from a series of tests on models 1, 2, 4, 8, and 12 ft. in height, provided the drain shown in Fig. 8 were placed at a section 216 in. down stream from the lower toes of the respective dams. From the results of the experiments with each of these models, it is possible that some sort of a curve could be prepared which might be extended to show approximately the action of the water on the final structure under a head of 100 ft.

Conclusions.—

1.—The author has not stated clearly how each experiment was carried on. In some places it is necessary for the reader to assume that the experiment was conducted under certain imposed conditions.

2.—The model dam used by the author was too small to give reliable results.

3.—The pressure, at all points observed in the tests, was affected by the drain; therefore, the results of the experiments are of little practical value.

4.—The drain in the model should have been placed 216 in. below the lower toe, instead of 36 in.

5.—The author has not disproved the "line of creep" theory.

6.—It would appear that too much dependence was placed on the impermeability of the material in the upper section of the dam.

7.—If the dam, as designed, were constructed to operate under the conditions imposed in the model, the flow under it would be about 320 cu. ft. per sec.

8.—It is the writer's opinion that the sheet-piling should be placed beneath the core-wall. If the core-wall in the partly completed dam is to be used, then the sheet-piling should be placed near the core-wall on the up-stream side. A water-tight connection should be made between the core-wall and the sheet-piling. The writer, being somewhat familiar with the conditions at the dam site, feels that, at best, there will be considerable seepage under the dam, and for this reason he would suggest that the slope of the down-stream face, below the 30-ft. berm, be made as flat as $3\frac{1}{2}:1$ or $4:1$. The proper slope for the down-stream face could no doubt be determined by extensive tests on a series of properly designed models of various heights.

Mr. Bacon. George M. Bacon,* M. Am. Soc. C. E. (by letter).†—The main objection to drawing conclusions from these experiments seems to be the assumption that the foundation as composed for the model represents sub-surface conditions at the dam site, an assumption hardly correct. What part of the foundation in the model corresponds to the actual condition on the ground, which allowed sheet-piling to sink "as deep as 32 ft. with one or two blows from a 1 700-lb. hammer"? The mountain streams formed "great cones, or fans, of very porous material". Was this material duplicated in the model, and, if so, where? In an experiment of this kind, it is vital to duplicate the actual conditions which are the subject of investigation. No ingenuity of observation and recording can minimize the importance of this. There is practically nothing in the paper showing how the foundation in the model was formed, or indicating its similarity to actual conditions.

The author's theoretical analyses are interesting, but, should they serve as a basis for the solution of the problem actually presented? If the premises are not correct, any deductions from experiment are not only of no value, but can easily be harmful as well as misleading.

Mr. Petterson. H. A. Petterson,‡ Assoc. M. Am. Soc. C. E. (by letter).§—The writer is a great believer in experimental engineering, and realizes that much of the advance made in engineering knowledge is due to the researches of careful and ingenious experimenters. He cannot believe, however, that experiments made on models with a depth of water of only 10 in., will bring forth results of any great practical value in designing a dam to impound water 100 ft. and more in depth. Our knowledge of the underground flow of water is not as complete as it ought to be. This is true especially of underground flow as affected by cut-off walls penetrating only part way into the porous stratum.

The most reliable experiments, however, would be those made on existing dams and weirs built on porous foundations. There are many structures in different parts of the world on which experiments could be made, and these could follow essentially the methods developed by Mr. C. S. Slichter.‖ Until such experiments are made, the writer, for one, would advocate following presents methods, a brief presentation of the underlying principles of which will be given.

The principles governing the design of an earth dam with impervious core-wall to impervious foundation need not be reviewed, as they are treated in any number of good textbooks. The problem of securing water-tightness in earth dams is essentially one of securing the maxi-

* Salt Lake City, Utah.

† Received by the Secretary, May 9th, 1916.

‡ Tientsin, China.

§ Received by the Secretary, June 6th, 1916.

‖ Described in Water Supply Papers, Nos. 67 and 140.

mum density of the material; and the laws governing this are known by the Engineering Profession, even though not universally applied. Strict adherence to these principles in earth dam construction involves extra cost, which is not always warranted by the results obtained. Mr. Petterson.

This discussion, therefore, will be confined to the principles involved in the design of an earth dam on a porous foundation of such great depth that an impervious cut-off wall to an impervious stratum is financially impracticable. It will be assumed that the dam will be made relatively impervious, and safe against ordinary methods of failure. The principles to be elucidated are the securing of stability against the possible destructive effect of water flowing under the dam (not through it); also, as it is assumed that the dam is to impound water in a reservoir, the investigation of the quantity of water lost by percolation is important from an economic standpoint, though it may in no way affect the stability of the dam.

A rational design cannot be made without a comprehensive grasp of the laws governing the flow of underground water. A very brief summary of present knowledge on these laws will be given, for the purpose of calling attention to the incompleteness of that knowledge and to make clearer the writer's comments on certain of the author's statements.

Laws of Underground Flow.

Hazen's formula, reduced to English units,* is

$$Q = 3.28\, c\, d^2 \frac{h\, A}{L}\; \frac{(t + 10)}{60} \qquad (1)$$

Slichter's formula† is

$$Q = \frac{16\,272\, d^2}{k}\; \frac{h\, A}{L}\; [1 + 0.0187\,(t - 32)] \qquad (2)$$

Baldwin-Wiseman's formula‡ is

$$v = c_1\, c_2 \frac{h}{L} \qquad (3)$$

In these formulas, c, c_1, c_2, and k, are coefficients. The values of c in Hazen's formula vary from 400 to 1 000. The values of k are tabulated by Slichter, and vary only with porosity. c_1, in Equation (3), is proportional to cd^2 and $\frac{d^2}{k}$ in Equations (1) and (2). c_2 corresponds with the temperature correction of Equations (1) and (2).

* Report, Mass. State Board of Health, 1892, p. 553; also, Turneaure and Russel, "Public Water Supplies", p. 96.

† U. S. Geological Survey, Water Supply Papers, Nos. 67 and 140; also, 19th Annual Report, U. S. Geol. Survey, Part II, 1899, p. 295.

‡ *Minutes of Proceedings*, Inst. C. E., Vol. CLXXXI, p. 15; also, Technical Paper No. 97, Govt. of India, 1902.

Mr. Petterson.

Q = discharge, in cubic feet per day, through the area, A;

A = area of cross-section, in square feet, normal to the line of flow;

h = difference of water surface, in feet, for two points distant L feet apart;

L = distance, in feet, measured in direction of line of flow;

d = effective size of sand grains, in millimeters, determined by mechanical analysis with sieves in Hazen's formula, and by the use of King's aspirator* in Slichter's formula;

v = velocity of percolation;

t = temperature of the water, in degrees, Fahrenheit.

These three equations all agree in several respects:

First.—The rate of flow increases with temperature.

Second.—The rate of flow increases with the first power of $\frac{h}{L}$, or, if h is constant, varies inversely with L.

Third.—The rate of flow varies with some power of the effective size of the sand grains.

By platting on logarithmic paper, a straight-line relation will be found to exist between Slichter's values of k and the porosity of the material. The same relation holds between porosity and the tabulated values of the transmission coefficient in Water Supply Paper No. 140. It may be shown that Slichter's tabulated results may be expressed in the following form:

$$Q = \alpha\, p^{3.3}\, d^2 \frac{h}{L}\, A\, T \qquad (4)$$

where p = porosity and T = temperature correction.

The effect of porosity is taken into account in all the equations. In Equation (1), the values of c vary with the uniformity coefficient, which is an indirect and approximate method of stating the effect of porosity. In Equation (3), the effect on porosity is introduced in the coefficient, c_1.

The writer believes that further experiments are required before a formula for underground flow will be developed, which will be even approximately as accurate, for instance, as that for the flow of water in pipes and other conduits. Based on present knowledge, such a formula will have the general form:

$$Q = \alpha\, p^n\, d^m \left(\frac{h}{L}\right)^r A\, T \qquad (5)$$

Our present formulas are applicable to sands up to an effective size of 5 mm. Hazen specifically limits the range of his formula to

* For description of King's aspirator, see 15th Annual Report, Agricultural Experiment Station, Univ. of Wisconsin, 1898.

Mr. Petterson.

sands of from 0.10 to 3 mm. effective size. The writer has introduced the exponent, r, in Equation (5) as necessary if the formula is to be applicable to all sizes of material. Thus, for large boulders, there is no doubt that r would approach a value of 0.5, as for flow in channels; and, for extremely fine material, such as silt and clay, r may become greater than unity.

Considering the equations for underground flow, we may, for convenience, combine the factors denoting effect of porosity, effective size, and temperature, and write an equation:

$$Q = \frac{K\ h\ A}{L}, \text{ or } p = \frac{K\,h}{L} \text{ for } A = \text{unity}.$$

The coefficient, K, may be taken as a constant for any given case, as for the gravel stratum under the dam described by the author. The head, h, is also fixed by the storage requirements. The only variables then are q and L. The hydraulic gradient equals $\frac{h}{L}$ and may have an infinite number of values, depending on the variable, L. There is, however, a definite relation between K and the character of the underground material.

The writer fails to grasp the author's meaning, when he refers to the hydraulic gradient of various gravels, as though there was only one possible hydraulic gradient for a given gravel. Thus, on page 325,* the author states:

"Having determined the hydraulic gradient of the underground material, a trial design was made to find what dimensions would be necessary in a dam constructed wholly of this gravel."

Again, on page 326*: "This combined material was then tested in the tank to determine the hydraulic gradient". On page 333,* there is a reference in similar vein.

APPLICATION OF FORMULA FOR UNDERGROUND FLOW TO DESIGN OF DAM.

The underground flow may endanger the dam in two ways: (1) The velocity of flow may be sufficient to carry away with it the finer materials in the gravel, and the so-called "piping" action results. If this keeps on indefinitely, it is only a question of time until the underground stratum becomes so porous that all the water in the reservoir will readily escape, or the stratum will settle, and the superstructure will go down with it. (2) The upward water pressure under the base of the dam may be great enough to overcome the weight of the superincumbent earth, and so-called "blow-outs" occur.

(1) Stability Against Piping.—Considering the equation, $q = \frac{K\,h}{L}$, it is obvious, from what has been already stated, that q, or unit dis-

* *Proceedings*, Am. Soc. C. E., for March, 1916.

Mr. Petterson.

charge, can only be reduced by increasing L. As the velocity is directly proportional to q, it, too, can only be decreased by increasing L, or, what amounts to the same thing, by increasing $\frac{L}{h}$.*

These coefficients are deduced from observations of existing structures, largely in India. They are not the results of experiments, but of compilations of data on structures which have proved to be safe. The writer cannot understand, then, why there is any lack of precedent in designing dams on porous sand foundations. The Laguna Weir is a notable example of a diversion dam founded on extremely fine silt. He agrees with the author as to the value, and even need, of further experiments, if this branch of engineering is to have a scientific basis, but cannot agree as to the value of experiments on models carrying only 10 in. of water.

A particular need for further investigation is the definite determination of the influence of cut-off walls, penetrating only part way through the porous stratum, in reducing the pressure head. According to the "line of creep" theory, this effect depends only on the depth of the barrier and the length of base, L; or, if L_c represents the depth of penetration of this cut-off wall, and h_s the reduction of the pressure head, then

$$h_s = \frac{2\,L_s}{\frac{L}{h}}.$$

The writer believes that the value of h_s depends, not only on L_s and $\frac{L}{h}$, but also on the ratio of L_s to the total depth of the porous stratum. If S represents the depth of the porous stratum, and other symbols are as before, then $h_s = \frac{B\,h}{L}\left(\frac{L_s}{S}\right)^n$ is the form of expression which, the writer believes, presents the value of the lost head. B is a coefficient, and n an exponent.

A point of practical importance is the difficulty encountered in making these cut-off walls impervious. Sheet-piling is assumed by some engineers to be practically impervious, but experienced men point out the tendency for deep piles to spread, and mention the difficulty of preventing this tendency, even with interlocking steel piles. As the work cannot be inspected, there is always uncertainty as to the efficiency of sheet-piling.

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* Tables of safe values of $\frac{L}{h}$, for material from fine silt to boulders, may be found in *Minutes of Proceedings*, Inst. C. E., Vol. CXCVII (1914), Paper No. 4004, by W. M. Griffith, or in a standard book like that of Thomas and Watt on "Improvement of Rivers".

Mr. Petterson.

(2) *Stability Against Upward Pressure Under the Base of Dam.*—The remedy against this method of failure is obvious. If y = the pressure head at any point, w = the weight per cubic foot of water, and m = the weight per cubic foot of the material in the dam; then wy is the intensity of pressure which is resisted by the weight of superincumbent earth. If z = the height of the dam at any point corresponding to y, then, for safety, mz should be greater than wy.

The foregoing discussion assumes that the material in the dam is impervious. If it is porous, the water plane will rise in the dam to heights corresponding to y. It is necessary, then, that z be greater than y. It is also necessary, of course, that the batter of the down-stream face of the dam be sufficiently flat to prevent sloughing of saturated material. The batter of the down-stream face will generally be sufficiently flat to ensure stability against sloughing, if it is designed in accordance with the requirements mentioned under "Stability Against Piping".

The writer believes that a more logical distribution of material is to make a flat down-stream face, with the up-stream face given the usual batter of earth dams, say 1 vertical to 3 horizontal. The material in the up-stream portion should be the most impervious. The reasons for this are well brought out by George L. Dillman,* M. Am. Soc. C. E. Such great care need not be taken in the construction of the lower part of the dam, though the material should be considerably more resistant to flow than that of the underlying gravel stratum. In other words, the engineer should see to it that the dam is constructed so that greater resistance to flow is offered at all points by the dam than by the underlying gravel, but the most impervious material should be on the up-stream side.

The author has reversed the usual method of distribution, in that he makes a steep down-stream face and extends the base up stream. The writer has prepared Figs. 14 to 17 in order to compare the usual design with that of the author. The total width of base in the author's design, as closely as can be determined from his Fig. 9, = 760 ft., and L_s, the depth of vertical barrier, = 125 ft. Then, by the usual theory, $L = 760 + 2L_s = 1\,010$ ft. A value of $L = 1\,000$ corresponds to a value of $\frac{L}{h} = 10$, which would be about the value given, in the tables previously referred to, for the gravel described by the author.

Figs. 14 to 17 show four designs with a value of $L = 1\,000$. Fig. 14 shows a section without any vertical barrier constructed in the gravel. The value of m is taken at 100 and that of w at 62.5. The value of z is computed so that $mz = 1.6\ (wy)$ or $z = y$. This gives

* In his discussion on the paper by M. M. O'Shaughnessy, M. Am. Soc. C. E., entitled "Construction of the Morena Rock Fill Dam", *Transactions*, Am. Soc. C. E., Vol. LXXV, p. 52.

Mr. Petterson. a factor of safety of 1.6 against failure by uplifting, where the material of the dam is relatively impervious.

Fig. 15 shows the design when an impervious cut-off wall, penetrating 125 ft. into the porous gravel stratum, is used. The effect of this is to increase L, making it $= 2 \times 125$, or 250 ft. Figs. 16 and 17 are for the same general conditions and assumptions, but they have a flat up-stream slope in accordance with the author's idea. The

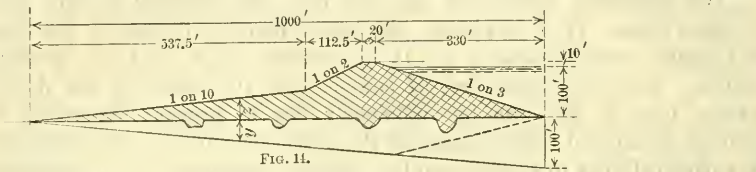

FIG. 14.

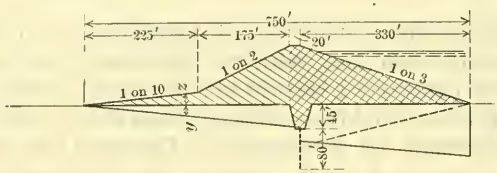

FIG. 15.

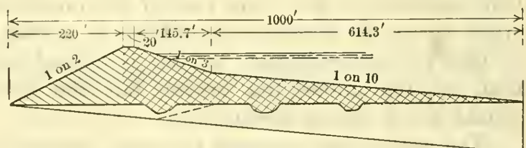

FIG. 16.

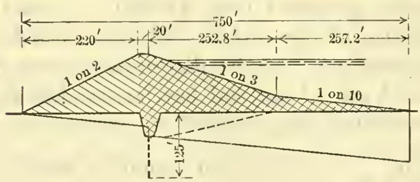

FIG. 17.

relative quantities of material per unit of length of dam are given in Table 4. The quantities include only those portions of the dams above the natural ground surface. The sections in Figs. 14 and 16 are directly comparable with those for Figs. 15 and 17. Attention may be called to several things in Table 4.

First, as far as total quantities are concerned, the section proposed by the writer has no material advantage over that proposed by the

Mr. Petterson.

author. The quantity listed as up-stream material is far less, however, for the dams shown by Figs. 14 and 15 than for those shown by Figs. 16 and 17. In view of the foregoing, the dams with the long down-stream slope can be constructed more cheaply.

TABLE 4.—VOLUMES, IN CUBIC YARDS PER LINEAR FOOT, FOR DAMS SHOWN BY FIGS. 14 TO 17, INCLUSIVE.

Up stream.	Down stream.	Totals.
754	876	1 630
754	524	1 278
1 242	448	1 690
841	448	1 289

Second, the dam with the long down-stream slope is likely to be much more efficient in reducing the rate of percolation under the dam. Unless extremely impervious material is secured for the shallow portion of the up-stream section of dams like those of Figs. 16 and 17, it is very probable that there would be percolation downward through the dam, near the heel, adding to the underground flow. In other words, the value of $\frac{L}{h}$ for a dam of this type is less than for a dam of the type shown by Fig. 14, even with the same length of base and the same depth of sheet-piling, or other cut-off wall.

Mr. Henny.

D. C. HENNY,* M. AM. SOC. C. E. (by letter).†—The design of a dam in a situation such as the author describes presents an interesting and difficult problem. In his conclusions he mentions several causes of earth dam failures, and states that his paper deals with one cause only, namely, springs or boils, which might produce piping under the base of the dam.

The usual percolating velocities are exceedingly low, far below the power of transporting material. The piping or blow-up phenomenon implies a combination of circumstances, relating to the material in place, essentially differing at particular points from the ordinary percolating conditions. In the case of clayey foundation, initial cracks may transmit a large portion of the available pressure to a point close to free exit, and may set up progressive erosion aided by arching. In the case of sand and gravel, strata of unusual openness to flow may be contiguous to layers of very fine sand. In very coarse material, the open spaces between pebbles and cobbles may be so great as to preclude true percolation and permit comparatively free flow and high velocity. The latter case is one which cannot be regarded as applying to foundations for high dams. The other cases are dependent on local devia-

* Portland, Ore.

† Received by the Secretary, June 6th, 1916.

Mr. Henny. tions from general homogeneity, which for large areas can hardly ever be known definitely. Moreover, the effect of such deviations cannot be ascertained by experiments with selected samples of materials placed in tanks or boxes.

The experiments conducted by the author do not appear to have had for their object the determination of a maximum gradient which would be safe against piping, but rather the most economical form of dam which would produce a maximum reduction of the water gradient, thereby minimizing the piping danger as well as seepage losses.

It appears to the writer that, whatever may be the danger from piping, it must be judged by examination of test pits and experience with existing dams. Usually, with the foundation material which the author describes, and with ordinary slopes of an earth dam, such danger is not great, and if necessary can be counteracted economically by a gravel blanket on the ground below the down-stream toe. Nor need there be any fear of bank sloughing, if gravelly material similar to that in the foundation is used in the down-stream portion of the dam. The real problem seems to be that of insuring against excessive seepage losses such as would render the reservoir useless.

In describing the history of the reservoir, the author states that when the dam was completed to a height of 30 ft., it was subjected to a head of 25 ft., at which time water escaped in considerable quantity from the down-stream toe. Though the quantity of water escaping is not stated, it is evident that if this is known or can be ascertained approximately a full-size experiment is at hand on which to base some judgment as to the seriousness of the problem.

A portion of this escaping water may have come through the dam proper. It is certain, however, that by far most of it passed through the dam foundation, which is described as being of a very porous nature and of unknown depth, roughly estimated at 240 ft.

If, at that stage of completion, the dam had a full width of base of approximately 500 ft., the water gradient producing this heavy seepage may have been 1 to 20, and a statement of the seepage per linear foot of dam would permit some judgment as to the practical admissibility, from the storage point of view, of such gradient for a full reservoir.

The author's determination of a safe gradient of 1 to 9 by vertical tank test is by no means conclusive. The essential feature, namely, the quantity of seepage with such gradient, is not stated. However, even if it were stated and were satisfactorily low, it is necessarily based on the use of samples of foundation material which, in the nature of the case, cannot represent any known sort of average of the deep masses of gravel, sand, cobbles, and boulders as they lie in place under the dam. Homogeneity cannot exist to any degree in material

of greatly varying sizes deposited by successive floods of varying intensity. Mr. Henny.

Assuming, however, that the samples used in the author's tests are representative of the general foundation, the tests made in a rectangular box with a model of a dam with varying depths of tight cut-off show the quantity of seepage under full head. For the first model tested, this averaged approximately 0.0040 sec-ft., and, for the second model, 0.0025 sec-ft. per lin. ft. of model. The writer understands that these quantities refer to the flow measured in the experiments, on a scale of $\frac{1}{120}$ of full size. If this understanding is correct, then, so far as the experiment goes, the deduction may be made that, for similar material in the foundation, the seepage for a dam built on the basis of the second model would be 120×0.0025, or 0.3 sec-ft. per lin. ft. of dam.

The longitudinal section shows the dam to be 400 ft. in length across the general river bed and 1 600 ft. in length on the adjoining bench. No data are at hand as to rise of rock under this bench. It may be interesting, nevertheless, to inquire as to what the total seepage under the dam would be if the rock were to rise but slightly away from the river. In that case the average gradient and seepage per linear foot for the bench portion of the dam would approximate one-half that for the full height of the dam. On such assumptions, a seepage would result of $\left(400 + \frac{1\,600}{2}\right) \times 0.3 = 360$ sec-ft. This quantity of seepage is clearly inadmissible, and the writer deems it likely that some of the foregoing assumptions may be known by the author to be erroneous.

Independent of the doubt regarding test samples being representative of material in place, there must be serious uncertainty as to the possibility of driving sheet-piling to a depth 80 ft. below the bottom of the cut-off trench, and as to the tightness of such sheet-piling when driven.

It will be noted that the final design of the dam as presented by the author shows an approximate gradient of 1 to 10 for full reservoir. This may be about twice the gradient which prevailed when there was 25 ft. of head against the present dam, at which time heavy seepage losses occurred.

A detailed study of the pressures as registered in the experimental box with the model of the dam reveals some marked inconsistencies, which, if the experimental results are to be made the basis for design, may require explanation. In considering this subject, the writer has confined himself to the use of experiments made under a full head of 10 in. representing 100 ft. on the scale of the experiment, and has selected for this purpose only those numbers, four in the first and three in the second series, for which pressures are recorded at all points.

Mr. Henny.

Individual differences of flow and pressure are rather large, the maximum variations from the average being as follows:

	First series: Experiments 9, 14, 19, and 24.	Second series: Experiments 4, 8, and 12.
Flow	7%	20%
Pressure	20%	13%

In order to eliminate individual variations, whatever may be their cause, pressures and pressure drops are figured on the basis of average values and are listed for comparison in Table 5.

TABLE 5.—Pressures and Pressure Drops.

	Average of Experiments.			
	1st Series: Nos. 9, 14, 19, and 24.		2d Series: Nos. 4, 8, and 12.	
Measured flow	0.0040 sec-ft.		0.0025 sec-ft.	
	Pressure.	Pressure drop.	Pressure.	Pressure drop.
Water toe	100 ft.		100 ft.	
		58.4 ft.		60.5 ft.
A	41.6		39.5	
Cut-off	50 ft. in 240 ft.	4.0	25 ft. in 240 ft.	11.8
B	37.6		27.7	
		2.8		5.7
C	34.8		22.0	
Cut-off	85 ft. in 240 ft.	21.9	125 ft. in 240 ft.	17.7
D	12.9		4.3	
		2.8		3.7
E	10.1		0.6	
		2.2		0.6
F	7.9		0	
		92.1		100.0

Table 5 shows the following rather surprising results as to pressure head destroyed by percolation: The pressure drop is greater from open water to *A*, from *B* to *C*, and from *D* to *E*, with smaller than with larger flow; the pressure drop is greater from *A* to *B* without sheet-piling, and with small flow than with sheet-piling and with large flow; the pressure drop is greater from *C* to *D*, in proportion to the flow, with shallow than with deep sheet-piling.

The drop from open water to the point, *A*, up stream from the points of cut-off, is 60% of the total head, in spite of the short distance of travel; so that the upper portion of the water gradient is steepest. The great loss of head at entrance appears to be inherent in experiments of this kind. It may well be doubted, however, whether

Mr. Henny.

such losses occur in the case of actual dams, where the area of entrance is very extensive, unless it is induced by silt deposits. Should no such loss with the actual dam be experienced, and should the pressure at *A* be 80 or 90% of the total head instead of 40%, the actual seepage losses may be double those deduced from the experiments.

In regard to the feature of the design consisting of a tight blanket up stream intended to lengthen the path of the water, the reasoning of the author is believed to be sound. The same method was advocated by the writer and was adopted in the case of the Grand River Diversion Dam built by the Reclamation Service near Grand Junction, Colo. The object in this case was the reduction both of uplift and of seepage. Fig. 18 shows a cross-section of this dam.

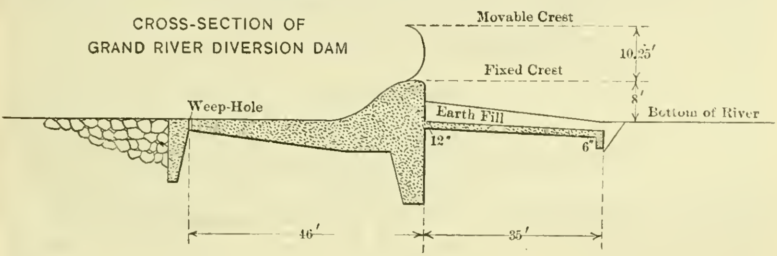

FIG. 18.

It may be stated that in this case measurements of uplift pressures were made through pipes placed in piers in the dam and ending in pockets of screened gravel under the foundation. The results indicate complete absence of entrance losses. They also show drop of pressure to be closely proportionate to distance along line of creep. It should be stated, however, that owing to delay in placing movable gates, the heads at the time of the two measurements were in each case only between 4 and 5 ft., and that measurements under a full head of 18 ft. may give different results.

Experiments of the character made by the author must always be of intense interest to hydraulic engineers and deserve full recognition.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE DESIGN OF A DRIFT BARRIER ACROSS WHITE RIVER, NEAR AUBURN, WASHINGTON

Discussion.*

By H. M. Chittenden, M. Am. Soc. C. E.

H. M. Chittenden,† M. Am. Soc. C. E. (by letter).‡—The writer believes that engineers will be interested in a brief description of the flood problem to which the drift barrier described by the author pertains. Those who have visited the Puget Sound country will recall that the overland route between Seattle and Tacoma is through a flat open valley behind a range of hills which rise 300 or 400 ft. above the level of the plain. This valley was once an arm of Puget Sound, but it has been filled up by the detritus brought down from the Cascades. Four principal streams have been the agencies in this filling process. Two of these—Cedar and Green Rivers—have always discharged to the northward through the Duwamish River into Elliot Bay, the harbor of Seattle. One, the Puyallup, has always discharged into Commencement Bay, the harbor of Tacoma. The fourth, the White River, largest of all and by far the heaviest detritus carrier, lies between the Green and the Puyallup, and drains the northern slopes of Mount Rainier. It has built up a detritus cone across the valley previously referred to, and this cone has reached the considerable elevation of 100 ft. above sea level where the stream debouches from the foot-hills. On the top of this cone, during the process of its growth, White River has flowed in unstable equilibrium for Mr. Chittenden.

* This discussion (of the paper by H. H. Wolff, M. Am. Soc. C. E., published in April, 1916, *Proceedings*, and presented at the meeting of May 3d, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Seattle, Wash.

‡ Received by the Secretary, May 15th, 1916.

Mr. Chittenden. indefinite ages, winding sometimes one way and sometimes the other. Since the valley has been occupied by white men, it has flowed most of the time to the north, and the name has attached to the course of the stream for a considerable distance in that direction; the connection to the south with the Puyallup bears the unromantic name of Stuck River. The boundary between King County, in which is the City of Seattle, and Pierce County, in which is the City of Tacoma, runs very nearly along the summit of the detritus cone. When White River has flowed north, King County has had to take care of it, with its destructive freshets, and when it has flowed south, the same burden has been thrust upon Pierce County. This situation has developed controversy between the counties which has occasionally led to litigation and sometimes to something worse.

This was the situation when the flood of November, 1906, which seems to have been the greatest since the valley was occupied by settlers, carried White River bodily over to the Puyallup and carved so deep a channel past the point of divergence as to indicate that the river would remain there for a long time. King County thought it would be good policy to make this action of Nature permanent, and commenced building a dam which should prevent the river from ever flowing north again; but, after a little work had been done, the plan was abandoned, probably because of protests from Pierce County. The writer was at the time in charge of the Federal Engineer District of Washington, with headquarters at Seattle, and was appealed to for advice and assistance in solving the difficult problem which had arisen. As no funds were available from any public source, he suggested local contributions sufficient to make a survey and report, and, in compliance with this suggestion, the sum of $4 000 was raised by the two counties and the four railroads operating in the valley. A voluntary board was organized consisting of the two county engineers, the four resident railway engineers, two U. S. assistant engineers, and the writer. A comprehensive survey was made, and the report of the Board's findings was duly made public.

The report recommended that White River be permanently held to the south slope, but that King County pay the major share of the cost of maintaining it there. The recommendation met with popular approval, but it was a long time before the Commissioners of King County could be swung into line, and then only as a compromise of litigation started by Pierce County. An agreement was finally reached, however, and the work is now being carried out substantially in accordance with the recommendations of the Board. These embraced a general rectification of the Puyallup River and an enlargement of the Stuck, the whole work to be fortified by an elaborate system of bank protection and levees. In order to relieve the stream of the

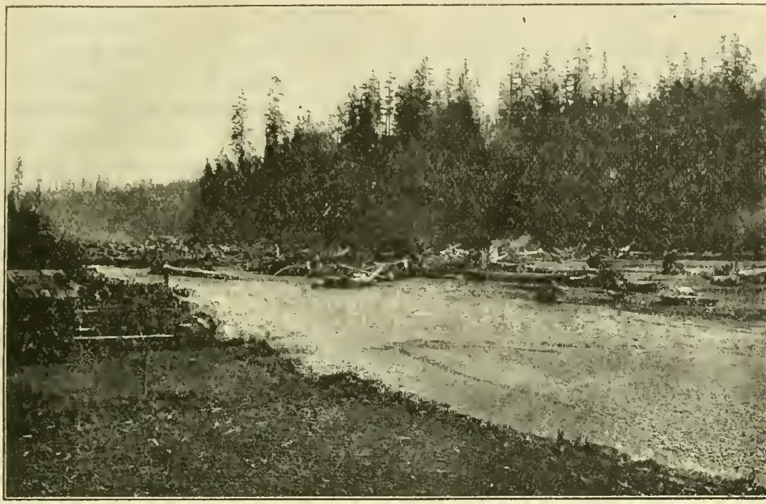

FIG. 12.—DRIFTWOOD BROUGHT DOWN BY WHITE RIVER IN THE 1906 FLOOD.

FIG. 13.—DRIFTWOOD BROUGHT DOWN BY WHITE RIVER IN THE 1906 FLOOD.

menace which comes from the enormous quantities of drift carried in flood time, the Board recommended the construction of a drift barrier on White River, and it is this structure which is the subject of the paper. Mr. Chittenden.

The method of functioning of this barrier is well described in the last paragraph of the paper. The writer will not discuss the technical details of the structure further than to say that they seem to be well adapted to their purpose. The Board contemplated a pile structure, but this would have proved impracticable because of the great depth of very heavy gravel, which would have made it impossible to secure the necessary penetration. The writer's only criticism of the work as constructed relates to its location. The Board chose a location at the narrowest part of the valley below the source of nearly all the drift. For some reason, of which the writer has never seen a satisfactory explanation, the location was moved 3 miles up stream to a site which, from a construction point of view, was certainly not superior to that selected by the Board, and has the serious defect of leaving about 3 miles of prolific drift-producing territory below it.

Figs. 12 and 13 show the White River and the driftwood brought down by the 1906 flood.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PRESERVATION OF SANDY BEACHES IN THE VICINITY OF NEW YORK CITY

Discussion.*

By Messrs. Lewis M. Haupt, Charles H. Higgins, Allen Hoar, and F. William Schwiers.

Lewis M. Haupt,† M. Am. Soc. C. E. (by letter)‡.—This interesting paper is limited to the vicinity of the New York entrance, but the principles involved are of general application, with local modifications, so that the writer ventures to call attention to certain features which seem to him somewhat obscure, in the hope of leading to a more definite application of the principles to general practice. Mr. Haupt.

The literature of the subject is prolix, and the publications of the Society, the Institution of Civil Engineers of Great Britain, and numerous other technical societies, contain elaborate discussions of both theory and practice; yet there seems to be room for further analysis, at least of the application of the theory to definite localities, as the results desired are not always attained.

Omitting, for the sake of brevity, the theoretical considerations, as being "somewhat idealized" as to the paths described by the forces which transport the drift, it will be more important to consider the facts as recorded by Nature and, from them, mould our conclusions.

The instrumentalities available for reclamation are jetties and groins, bulkheads and sea-walls "properly applied". This is the crux of the matter, for, in many instances, bulkheads and jetties have proven more injurious than beneficial, and as the local conditions are subject

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* This discussion (of the paper by Elliott J. Dent, M. Am. Soc. C. E., published in May, 1916, *Proceedings*, and presented at the meeting of June 7th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Cynwyd, Pa.

‡ Received by the Secretary, May 27th, 1916.

Mr. Haupt. to frequent changes, due to occult cosmic forces, it is very difficult to adjust a permanent structure so as to give satisfactory results under the composite conditions, which is all that the engineer can do.

As to "jetties and groins", a distinction is made, based on their relative lengths, but it would seem better to limit the term to the word "jetty", as a projection from the shore across the strand, than to "groin or groyne", the angle formed by the intersection of two surfaces.

The writer believes that the statement as to their effects, namely, that they "must inevitably cause a wastage of beach material", should be taken *cum grano salis,* for, in the locality in question, short jetties have had a very decided effect in building up the beach without apparent injury to the leeward properties; for instance, at Far Rockaway two jetties (Fig. 10) were erected, about 4 years ago, concerning which the parties say: "The work is highly gratifying as we have gained at least 500 ft. in the width of beach and raised the crest of it away above the top of the piles forming the jetties." The writer is informed, also, that similar jetties built at Long Beach are likewise buried out of sight.

The extensive works now under contract to protect the tracks of the Central Railroad of New Jersey at Seabright, consisting of some thirty jetties reaching out 200 ft., have collected some of the drift at the southerly end, but have not recovered the original low-water line, which was more than 600 ft. out a few years ago. These jetties supplement a heavy bulkhead filled with stone, and this, in severe storms, is scaled by the breakers, which fall over on the track and destroy it.

The influence of the prevailing winds must also be carefully considered, for it is a factor in the accumulation of material, independently of the drift carried by waves and currents. The low, short jetties at Belmar, N. J., during the winter of 1915-16, were completely covered by this wind-driven sand, and under normal conditions they do arrest the northwardly moving drift in the southerly groins, filling them to the crests and traveling over.

Many of the bulkheads along the New Jersey coast have been denuded entirely of their back-filling, and have been further protected by lines of stockades filled in with stone, yet they have not recovered the lost ground, nor do they protect the properties in their rear from the violence of the waves, as has been exemplified so fully by the storms of the past few years, so that it would seem to be unwise to place much stress on this form and location of defensive works. Fig. 11 shows a reinforced concrete jetty at Long Branch, N. J., in February, 1916; the bulkhead was denuded and the back-filling gone.

The statement that "the only salvation for * * * that beach [Asbury Park] lies in the construction of sea-walls of sufficient strength to combat the waves until such time as new berms are formed, if such time ever comes", would seem to be somewhat discouraging,

FIG. 10.—HOOKED JETTIES NOW BURIED UNDER THE DEPOSITS WHICH THEY HAVE MADE.

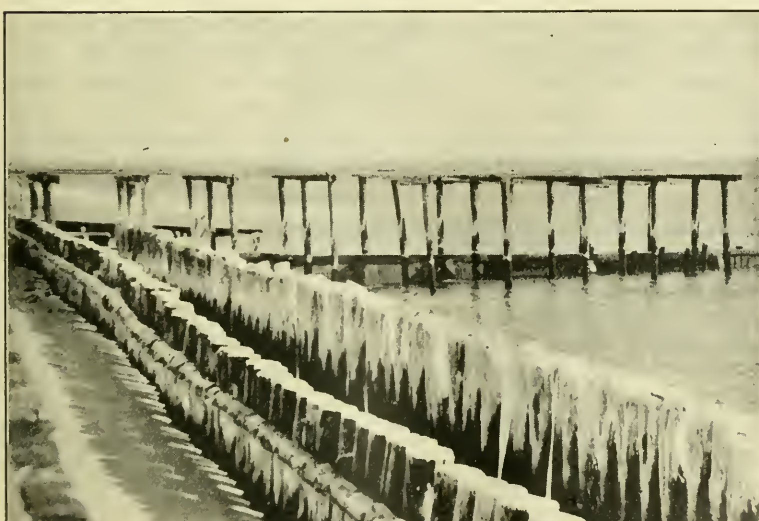

FIG. 11.—REINFORCED CONCRETE JETTY, LONG BRANCH, N. J., FEBRUARY, 1916. BULKHEAD DENUDED AND BACKFILLING GONE.

were it not for the fact that, up to this time, no dependence has been placed on "sea-walls" but only on short spur-jetties. Mr. Haupt.

The causes of the temporary stoppages of the drift along the south shore of Long Island, as well as the quantitative movements of the drift and the menace to the channels crossing the New York bar, are matters worthy of very serious attention.*

The rapidly increasing value of the riparian lands in the vicinity of our great centers of population renders the careful consideration of these physical problems timely and important. The New Jersey State Geological Survey report of 1905 contains an extended paper on the changes along that coast which may serve to aid in the solution of these complex problems.

Charles H. Higgins,† M. Am. Soc. C. E. (by letter).‡—This paper is most interesting, and the writer congratulates the author on his lucid analysis of the phenomenon of beach erosion, particularly on the coasts of New Jersey and Long Island, and confirms, in general, his observations on littoral drift. However, between the premises laid down as to littoral drift and the conclusion, reached by the author, that: "damage * * * must inevitably result to the beaches as a whole if the erection of structures that interfere with littoral drift is allowed to continue", there is a wide gap, which it does not appear to the writer has been logically crossed, and which is certainly not in accord with his observations. Mr. Higgins.

The writer has described§ the theory and construction of a system of groins or jetties, constructed at Asbury Park, N. J., under his supervision, 9 years ago, and the results obtained.

Fig. 7 illustrates thoroughly the typical action of waves on a sand beach. In this problem of erosion on a sandy coast, though the masses dealt with are tremendous, the unit is very small, namely, a grain of sand; and, just as the unit of a great army is a single man, and the movements of that army, as a whole, are dependent on the behavior of each of the units, so, if the grain of sand is controlled, by extension the mass may be controlled.

The phenomenon of littoral drift apparently results when the grains of sand are not moved by the waves directly fore and aft, but are sawed along, as indicated by Fig. 7. B_2 is the critical point, for when the line containing the series of points, B_2, moves toward the shore, the observer at once remarks that we are losing beach. On the other hand, when the line moves seaward, beach is made.

* Some allusions to these matters may be found in the *Journal* of the Franklin Institute for February, 1905, and in the *Proceedings* of the Brooklyn Engineers' Club in a paper on the "Reclamation of Coney Island."

† New York City.

‡ Received by the Secretary, June 7th, 1916.

§ *Engineering News*, April 16th, 1914.

Mr. Higgins. Now, the purpose of a system of groins may be single or twofold; that is to say, it may be designed to prevent this critical line, marked "Plunge Point" on Fig. 7, from moving shoreward, in which case the groins end on this particular line; or it may be intended, also, to force this critical line farther out, and thus increase the width of the beach, in which case the ends of the groins extend beyond B_2, thus forcing the shore current farther out, and consequently making beach. An important consideration in such a design is the distance between the several groins. By Fig. 7 the author has indicated clearly the typical path of a grain of sand by lines which form the figure of a saw tooth, B-B_1-B_2. A low groin to the left of B and another to the right of B_2 would, by interrupting this movement, prevent this sawing away of the beach.

The critical line, which the author has named the "plunge point", is really the fighting line between land and sea—the first-line trench, as it were—and as this advances or recedes, a gain is made by one or the other of the contending forces.

Considering the shore as a whole, it is hard to conceive what damage can be expected to result from fixing this "plunge point" line, either where it may be in the particular year the groin system is built, or a few feet or even a few hundred feet farther out. The phenomenon of littoral drift proceeds uninterruptedly on the new line. The author, on the other hand, seems to prefer a bulkhead constructed apparently along the line on Fig. 7 marked "Upper Limit Reached by the Uprush". Where bulkheads have been built without a groin system in front, it has usually resulted in the "plunge point" line moving back to the toe of the bulkhead; in other words, the beach is lost; the shore, however, is maintained as long as the bulkhead remains intact.

Now, the only apparent difference in effect on littoral drift is whether that drift occurs along a line through B_1 or along a line somewhat in advance of B_2. The only difference in material, added or subtracted, is the beach between the two lines; and a matter of a few hundred feet, in dealing with an adjustment in masses like sea and land, contains such a comparatively minute quantity of material as to be negligible in considering the total volume.

In very many cases, the protection of the shore, without maintaining a beach, is not sufficient; for example, at Asbury Park, with its mile of ocean front, it is of the greatest importance that a broad sand beach be maintained, and, in general, a shore line with a beach in front of it is preferable to one in which simply a bulkhead marks the limit between land and water. It should be borne in mind that such coasts are developed or used for summer colonies. There are also economic elements entering into this problem. A bulkhead to resist the direct and unimpeded action of the ocean is no trifling affair.

It is the writer's opinion that, in most cases, where shore front for residence purposes is involved, economy, utility, and attractiveness are all best served by a system of construction designed to hold what the author names the "plunge point" line at some distance in front of the shore line—that is to say, dry land—and that this may be accomplished by a properly designed and constructed system of groins or jetties, with a light bulkhead in the rear to prevent wash, the bulkhead being protected from the direct attack of the sea by the beach, which in turn is preserved from erosion by the system of jetties or groins. Mr. Higgins.

It is noteworthy that the author limits his discussion of the New Jersey Coast to that part of it above Asbury Park. The writer is of the opinion that, if the coast above Ocean Grove and Asbury Park received a treatment similar in principle, a similar satisfactory result would be obtained and at a minimum expense.

A massive bulkhead seems to appeal to the imagination, just as a masonry fort does; but, where the impressive fort fails, the simple trenches prove effective. Thus, in preventing the advance of the sea, the low groins hold the line under conditions where the massive bulkhead is smashed to bits.

Allen Hoar,* Jun. Am. Soc. C. E. (by letter).†—The author of this valuable paper is to be commended on the manner in which he has brought this serious and often difficult problem of beach control to the attention of the Profession. The paper sets forth clearly and concisely many of the difficulties to be encountered in work of this kind, and points out the necessary investigations to be made before such work can be planned with any certainty of ultimate success. It should be a warning to those who would undertake the planning and building of beach structures without first making careful and thorough investigations extending over a sufficient period of time, and taking into consideration all probable weather conditions. This, unhappily, has not always been done, and many unnecessary failures have resulted. Mr. Hoar.

The writer has been fortunate in being able to make a close study of the beach conditions at Long Beach, Cal., for the past 5 years, and has watched with interest the encroachment of property owners on the waters of the Pacific Ocean along that section known as the West Beach. In this instance, the beach adjoining property has become valuable as a desirable location for hotel-apartment houses and other tourist accommodations, but, as this particular piece of property is just a narrow strip facing the Pacific Ocean on the south and backed up on the land side by high bluffs and the Pacific Electric Railway yards, offering no suitable approach from that direction, it was necessary to build an approach from the east along the beach front. This

* Pasadena, Cal.

† Received by the Secretary, June 7th, 1916.

Mr. Hoar. was also deemed desirable for use as a promenade. For this purpose, and to add to the attractiveness of the beach front property, it was decided to build a wide concrete walk and bulkhead.

The error in judgment here and the difficulties to be met in carrying out the plan adopted were due to the fact that, for the greater part of its length, the southerly line of this property was only a few feet back from the ordinary high-water line, and the walk as constructed, from the property line south, encroached to a considerable extent below the high-water mark and still-water level. The consequence of this has been that, during extreme high water of spring tides, whether accompanied by heavy storms or not, great damage is done to both the bulkhead and walk, and the beach lying in front of the bulkhead is destroyed. Each year since its construction some portion of this bulkhead and walk has been torn out and has had to be rebuilt, and, in fact, it has never been possible to finish the construction at the western end, this section of the work having been destroyed before completion time and again at each attempt.

The bulkhead at and supporting the outer edge of the walk consists of a single row of reinforced concrete sheet-piles, about 6 by 12 in. in section, and from 14 to 16 ft. in length, cast tongue-and-groove fashion. The reinforcement consisted of four vertical rods, one in each corner of the pile, and projecting several feet above the head of the pile for anchorage into the parapet wall to be built after the piles had been placed. The piles were raised by a light pile-driver mounted on skids, and jetted and driven through the sand to penetrate a layer of clay at a varying depth of from 12 to 14 ft. below the surface. After the piles had been driven to place, a concrete cap was cast in place along the top of the row of piling, and the bulkhead was then back-filled to the level of the cap. The walk, of 6-in. concrete, was then laid, the outer edge being supported on the cap and the remainder resting on the back-fill. Along the outer edge of the walk and over the row of piling a reinforced concrete parapet wall was next cast in place. This wall was built in panels and reinforced horizontally by rods running through its base and through its coping. It was reinforced vertically by the rods which were left projecting above the tops of the piling, serving to anchor it firmly to its base. This construction would have been adequate under all ordinary circumstances, if the bulkhead had been placed at or back of the high-water line, but, placed where it is, in from 1 to 2 ft. of water at ordinary high tides, it is subject to severe impact which becomes terrific with the force of the larger breakers accompanying stormy weather.

The construction of this bulkhead has had a very marked effect on the destruction of beach in front of it. This is undoubtedly because the bulkhead is only a few feet shoreward of the plunge point of the incoming breakers, thereby limiting the extent of the up-rush and its

sand-carrying power to a point where the power of the back-flow is predominant; and, in the case of unusually high water, when the plunge takes place almost on the bulkhead, the force and action of the plunge is felt clear down to the sand and results in excessive scour and erosion. This is due to an almost entire absence of back-flow at this point, and, therefore, instead of spiraling over a comparatively strong backflow as is usual, the plunge is carried right to the bottom. Mr. Hoar.

The conditions here are peculiar, in that there is practically no littoral drift of sand or other beach-building material, and therefore no method can be advanced for the rebuilding of the beach by bringing the natural forces into play.

The sand composing this beach is very fine, and contains a very large percentage of extremely light material. The surface of the sand along the beach slopes normally about 2 ft. per 100 ft. to a point about 300 ft. from the high-water line, and from this point it shelves off gradually until it strikes an almost vertical bank about 600 ft. off shore, where the water has an average depth of about 35 ft. There exists just beyond this bank an off-shore current flowing westward, although with no very great force except in case of storm.

The light character of the beach sand allows it to be set in motion by even slight agitation of the breakers, and, when acted on by the large swells raised by a storm, this light material is carried away out by the undertow until it reaches the off-shore current, by which it is carried out to deep water. During calm and low tide much of this sand is carried only to the outer breaker line where it is again picked up, carried shoreward and deposited on the beach by the up-rush. This is shown by the fact that during calm weather, when the breakers are small, the beach builds up very flat, and, under the influence of the large swells after a storm, it is rapidly cut away between the high- and low-water lines, leaving a comparatively steep slope.

The tidal drift along this beach is from east to west, but the in-shore drift is so slow that it is not of the slightest value in transporting sand to build it up.

From the foregoing it can be understood that, in this case, the large sand-laden breakers accompanying heavy storms cannot, because of the location of the bulkhead, aid in the preservation of the beach by building up a new berm, as is the general result as pointed out by Mr. Dent. On the contrary, erosion is accentuated, and a considerable portion of the sand put in motion is transported by the heavy undertow to the off-shore current, where it is lost to the beach for all time.

F. William Schwiers,* Assoc. M. Am. Soc. C. E.—The speaker has had some experience on this subject on the south Long Island shore, and also on the New Jersey shore; and has read considerable on the Mr. Schwiers.

* New York City.

Mr. Schwiers. topics referred to. The Library of the Society contains some volumes written by Mr. Case or Mr. Allanson-Winn, describing the Case system of low groynes. The speaker believes that this system—where its use is feasible—is the best method of shore protection. Briefly, it consists of low barriers, built on the beach, and started below the low-water line. These barriers catch the drift carried by the along-shore currents and build up the beach. As the latter is built up, the groynes are continued shoreward on the proper incline, which corresponds to an elliptical curve, and has been termed the ellipse of repose. The waves ascend the inclined surface until they have spent their energy, and then recede harmlessly. During storms the low groynes are entirely submerged, and are protected by the overlying water.

The Case system has been used extensively in England, but is not adapted to the Jersey shore, because the property owners there have encroached too far on the ocean. In some cases bulkheads have been built even beyond the low-water line, so that no beach is visible at low tide.

The method of protection used along the Jersey shores is timber and pile bulkheads, parallel with the beach, behind which beach sand has been filled in, and low jetties running seaward. The jetties, generally speaking, are low structures entirely submerged during heavy weather, their purpose being to build up the beach in a manner similar to the Case groynes. The destruction of bulkheads takes place during very high tides accompanied by storms from certain directions. On the south Long Island shore erosion takes place during northeast storms and on the Jersey coast during storms from the southeast. The heavy waves, striking the bulkhead, are deflected upward and downward, creating a semi-fluid mass of the beach material at the foot of the bulkhead. If the sheet-piling has not sufficient penetration, the material back of the bulkhead soon becomes a semi-fluid mass and escapes under the sheeting; this leaves the bulkhead without support, and its destruction rapidly ensues. To support the bulkhead against this contingency, during late years, a second row of brace-piling has been driven about 20 ft. back of the bulkhead, to which horizontal brace logs are attached and connected to the bulkhead piling several feet from the top. This method has been fairly successful, provided there has been sufficient penetration for both the sheet-piling and the round piling. There is sufficient elasticity in this construction, in connection with the material back of the bulkhead, to absorb the shock of the waves. Heavy masonry bulkheads have not been successful along the Jersey shores, and they are not advisable unless an absolutely firm foundation can be obtained and the footing of the wall can be protected from scour by sheeting with deep penetration.

Mr. Schwiers.

The situation on the Jersey and Long Island shores is probably aggravated by littoral currents created by the flow of the Hudson. This river, flowing into the ocean, creates shore currents flowing northward along the Jersey coast and westward along the Long Island coast, eroding the southern Jersey shore and eastern Long Island shore, and carrying the material northward and westward, respectively, thus accounting for the formation of Sandy Hook and Coney Island. These littoral currents are reinforced by storms from certain directions, *viz.*: southeast on the Jersey shore and northeast on the Long Island shore; and when both these conditions are coincident with an abnormally high tide, great erosion and destruction ensue.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PROPERTIES OF BALSA WOOD

(*Ochroma Lagopus*)

Discussion.*

By A. P. Lundin, Esq.

Mr. Lundin.

A. P. Lundin,† Esq.—The speaker's attention was drawn to this wood many years ago, during voyages to tropical countries, *viz.*, Central and South America, Central Africa, and also India, in all of which the same species can be found; and he first remarked it when a number of natives came floating down a river on a raft made up of balsa logs. The logs were covered more or less with bark, and where this was chipped away, the hard surface still remained, which is found on the outside of balsa logs, under the bark; the ends were covered with tar, or some waxy substance.

The natives, particularly in Central and South America, use such rafts to float their products to the sea coast, and seldom use them more than once, for one reason, because it would be difficult to bring the rafts up against the stream, and because the wood absorbs water very readily and the raft is more or less water-logged after arriving. Of course, in solid logs, with the ends closed up, the absorption is not so rapid as when balsa is cut up in planks and freed from bark.

Later, when engaged in the life-saving equipment business, it was brought to the speaker's attention that some crude attempts had been made to use balsa in life preservers. On taking over a boat shop in Long Island City, a quantity of balsa was found there, and,

* This discussion (of the paper by R. C. Carpenter, M. Am. Soc. C. E., published in May, 1916, *Proceedings*, and presented at the meeting of June 7th, 1916) is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

Mr. Lundin. on inquiry as to its purpose, it was learned that experiments had been made with it in life-belt manufacture, but that the wood absorbed water so rapidly that the belts had to be made two or three times as large as the ordinary cork life-belt to assure the required buoyancy. Subsequently, chemical experts were put to work to devise methods for making the wood non-absorbent.

First, painting was tried, but, owing to the peculiar nature of the material, the paint was rapidly absorbed, and coating it over and over meant having just as much paint as wood, which added greatly to the weight. Then varnishing was tried, but, owing to the moisture left inside, the varnish cracked and blistered off.

Next, several mixtures of paraffin, asphaltum, gilsonite, etc., were tried, which gave a fairly good outside coating, penetrating about $\frac{1}{4}$ in. on the ends and about $\frac{1}{16}$ in. on the sides, and the problem was apparently solved. However, before long it became evident that, owing to the cellular structure of balsa, which is mostly pith, and the great quantity of moisture sealed up in the wood by the impervious surface treatment, dry-rot developed even sooner than in the untreated balsa.

Just at the time these difficulties became apparent, Col. Marr's water-proofing process was brought to the speaker's attention, and after numerous experiments with the new method, it was successfully and practically applied.

The United States Government has tried out balsa life-preservers, life-buoys, etc., as compared with the cork articles, for a period of 49 days (24 hours per day), at the end of which period the cork preserver had lost all its buoyancy and the balsa preserver still retained the buoyancy stipulated in the Government requirements.

A few years ago, while working on the buoyant-material proposition, it was considered that, as balsa, owing to its peculiar structure, was so advantageous for use in buoyancy products, it might also be adaptable for insulation purposes, and accordingly experiments in that direction were begun. The first ice-box made of the new material was on the speaker's motor boat, and the results were surprising. All during the hot summer weather, ice was put in the box on Friday or Saturday, and on the following Friday or Saturday the temperature in the box would still be quite low and some ice still left in the box.

Naturally, all first work in the line of balsa insulation was more or less crude, and the importance of scientific investigation was soon realized.

It was particularly fortunate that Professor Carpenter became interested in this material. The speaker well remembers that when he first spoke to him about this wood, and stated that it was all pith and no fiber, he and the gentlemen in his company looked very

skeptical. However, he was sufficiently interested to visit the Welin plant, intending to remain there half an hour, but he spent practically a whole day, and when last seen on that occasion, he had all his pockets full of balsa, and he has been steadily devoted to the investigation ever since. Mr. Lundin.

The speaker does not pretend to be an expert on insulation or non-conductivity, but looks at this material from a practical rather than a scientific viewpoint.

The principal feature in insulation material is, of course, that it must be a good non-conductor, but no doubt in the future engineers will also consider structural strength, and the possibility of making up complete homogeneous units will also be considered in judging the efficiency and value of insulating material, particularly where it is to be used in making ice-boxes and as insulation for buildings, in ships, and in railroad cars.

The principal consideration is a commercial one; in other words, good engineers always try to obtain the highest total efficiency, and commercial men want it and are willing to pay for it.

In shipping, for instance, it is known that almost any ship can be insured if built to certain requirements, such as Lloyds, and it can be insured at the lowest rates (except, of course, in time of war). All cargo on such ships can also be insured at reasonable rates, except one class, and that is perishable food stuffs carried in refrigerator compartments, which are always carried at the shipper's or consignee's risk. Neither the steamship companies nor the insurance organizations will place insurance on such goods, except for the event of total disaster to the ship. Why? Not because the science of refrigeration has not kept pace with the science of naval architecture, but because of the fact that if a break-down occurs in the refrigerating machinery, the cargo will spoil, as the insulation is not reliable enough to keep the temperature sufficiently low until the machinery can be repaired and the system put to work again.

The speaker had an experience of this kind, many years ago, when on board a meat ship running from Australia to London. The machinery broke down while running through the Red Sea, and more than half the cargo spoiled in less than 24 hours.

A few years ago, in a meat market in Seattle, a new refrigerating plant, which had what might be called ordinary commercial insulating material, broke down, and before new parts could be obtained to replace the broken ones, and the machinery put in working order again, the damage to the meat in the market amounted to more than the cost of the refrigerating plant.

Therefore, when it comes to efficiency in insulation, there is still room for improvement. Perfection cannot be attained, but balsa wood will surely help to make insulation perfect, as it is not only a

Mr. Lundin. very efficient non-conductor, but has sufficient structural strength, and, through its physical properties, permits of constructing units with practically unbroken insulated surface walls.

A small ice-box, or pony refrigerator, made by the Welin Company, is of balsa wood, 2 in. thick, about 36 in. long, 21 in. wide, and 22 in. deep, and weighs about 30 lb. Such a box could not be made up of any other known insulating material. It is strong enough to stand severe jars, and a man could jump on it without straining it unduly. Of course, other woods will stand more rough usage than balsa, but, to meet this factor of additional strength, particularly on the surface, paneling made from the bark and waste of the wood is applied to the outside.

A small container, on the order of a thermos bottle, but in the form of a box made of 1-in. material, has a capacity of about 1 cu. ft. and weighs 6 lb. When going on an automobile trip, or something of that sort, the "lunch" can be placed in such a container—whether it is to be kept hot or cold. If it is wanted cold, a little ice should be put in to keep it so.

Butter has been sent all the way from Virginia to Southern California in such boxes, at an average outside temperature of 82°, and the trip took 8 days, by the slowest route. Yet, when the boxes arrived at Los Angeles, the butter was still hard and frozen.

Even if balsa had 30% less efficiency as a non-conductor, the speaker believes that it would meet a very common requirement for insulation, not satisfied by another material lacking in structural strength, which makes it possible to eliminate all leakage of heat through imperfect joints, or by use of cement or nails which may be classified as good conductors. Other insulating materials are almost entirely limited to use as a lining for a structure built of good conducting materials.

The speaker has a dream of perfect refrigerated transportation and conservation which may be of interest: It is growing more and more expensive to live in America and in many other countries. Food seems to be getting more scarce and more expensive all the time; heat in the winter and cold in the summer are rising in price, in short, the cost of every daily need is "going up."

Much of the increase in prices is due to waste, and, if this waste can be eliminated, it stands to reason that prices will go down. If foodstuffs could be transported, stored, and kept in first-class condition, not only the tremendous waste which exists to-day would be done away with, but food would be purer and would retain its full nutritive values, and this is very important, as there is no doubt that cold-storage food will have to be used to a large extent.

By instituting a continuous chain of proper and effective cold-storage and transportation facilities, which would insure the safe

delivery of foodstuffs with a minimum of deterioration and a minimum of waste, some of the chief causes of the high cost of living would be removed, and this balsa insulation system could be spread, not only over the Western Continent, but all over the world. Foodstuffs would travel from producer to consumer in balsa containers—parcel post boxes, pony refrigerators, automobiles, railroad cars, ships—to be stored in balsa-walled storage warehouses, and, when delivered, would be put away in balsa house refrigerators. Mr. Lundin.

The scope of this enterprise is very great. Insurance and guaranties would be furnished on such shipments, for with such highly improved methods to lessen the possible loss, insurance companies would find it to their interest to establish a standard specification on which basis the risk on perishable foodstuffs in transit could be covered.

The time is not far off when it will pay every architect to line his buildings with 1 or 2 in. of balsa wood, not only as an insulation lining but as a finish, instead of plaster and such coatings, which crack and fall down. Very attractive effects can be obtained with paneling in the interior of buildings.

There are a thousand and one uses for balsa, and in the future new ones will continually develop. Thanks and grateful acknowledgment are due to Professor Carpenter for the earnest scientific work he has done in investigating this wood.

[illegible]

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

SURGES IN AN OPEN CANAL

Discussion.*

By Messrs. Karl R. Kennison and Irving P. Church.

Karl R. Kennison,† Assoc. M. Am. Soc. C. E. (by letter).‡—The author's determination of the height of the surge in an open canal, following a sudden interruption of the flow, appears to be based on sound theory. It is particularly interesting to the writer on account of the intimate relationship between this surge and the hydraulic jump, the discussions of which are published with the writer's paper "The Hydraulic Jump, In Open-Channel Flow at High Velocity".§ The author's treatment of the hydraulic theories involved is complete, and requires little to be said in addition. The same conclusions, however, may be reached in a different way, at the same time bringing out some interesting characteristics of the hydraulic jump which were suggested by reading this paper; also, a formula for the canal surge is submitted herewith which is simpler than that deduced by the author. Mr. Kennison.

There are points of difference between the ordinary hydraulic jump or standing wave and the author's receding wave which at first seem inconsistent, but which are really in agreement. It has already been shown§ that in an open channel, carrying a certain quantity of water under a certain head, there are only two surface levels at which the water can flow steadily. If the velocity is less than $\sqrt{g \times \text{depth}}$, it is flowing at the upper alternative stage, and, if a dam of the proper

* This discussion (of the paper by R. D. Johnson, Esq., published in May, 1916, *Proceedings*, but not presented at any meeting), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Providence, R. I.

‡ Received by the Secretary, June 23d, 1916.

§ *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 338.

Mr. Kennison. height is interposed, it will drop to the lower alternative stage. If the velocity is greater than $\sqrt{g \times \text{depth}}$, it is already at the lower stage, and may jump to the upper stage by meeting either an obstruction, which, if of the right height and smoothness, may avoid all but incidental eddy losses, or a change in channel conditions sufficient to cause the normal jump with its eddy losses, as ordinarily observed. The question may arise: how can the level in a low-velocity canal, which is already at the upper alternative stage, jump any higher on the sudden closing of a gate, even higher than the level of quiet water before its acceleration into the canal entrance, as the author states?

The explanation is that the conclusions previously drawn, with reference to the hydraulic jump, assumed that the jump was in every case stationary, not moving up or down stream. Now, if this standing wave travels along the channel, we may, since velocity is only relative, correct all the velocities by an amount equal to the velocity of the wave, and then the conclusions regarding the hydraulic jump apply correctly to all such moving waves. For example, a suddenly interrupted canal flow, though flowing apparently at the upper low-velocity stage, is approaching the (receding) wave at so high a relative velocity that it is relatively at the lower stage and capable of jumping higher. In fact, when we consider the standing wave or jump as movable along the stream, instead of stationary, there are, instead of two, an indefinite number of possible water levels. It can even be shown that absolutely still water in an open channel can theoretically be made to drop to any lower level or to rise to any higher level by the passage of a standing wave.

This relationship between the hydraulic jump and the surge in an open canal is already clear to one who has followed the author's admirable mathematical analysis. At the risk of some uninteresting repetition, an attempt is made to say the same thing in a different way, and also to show graphically some peculiarities of the hydraulic jump and its relation to the canal surge. The writer has found that elementary diagrams like these are often helpful in getting a clear idea of the subject.

In Fig. 1, two smooth obstructions or dams are assumed to be kept a uniform distance apart and moved along the bottom of a rectangular flume containing still water, with the result that the water level drops, as shown, and rises again to still water, neglecting, of course, friction and incidental eddies. The dimensions are chosen so that direct comparison may be made, if desired, with Figs. 3 to 8 in the writer's paper, "The Hydraulic Jump, In Open-Channel Flow at High Velocity". Higher dams moved at lower velocity would cause a drop lower than shown, and lower dams at higher velocity a drop not as low. The same height of dams, moved much more slowly than shown, would cause only a local depression over each dam. They could not

be moved faster without raising the level of the still water ahead, until their velocity is increased to that shown in Fig. 2. Then the water would rise theoretically as shown and drop again to still water, neglecting friction and incidental eddies, which, of course, would

Mr. Kennison.

RECTANGULAR FLUME FRICTION NEGLECTED

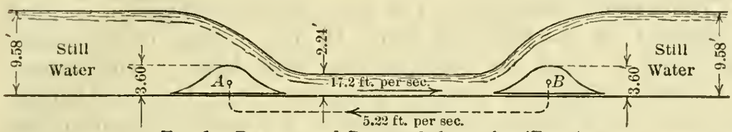

FIG. 1.—Dams A and B moved through still water.

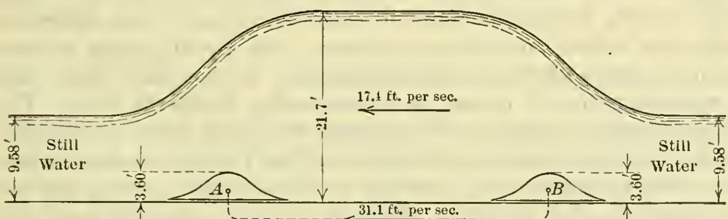

FIG. 2.—Same as Fig. 1, except that A and B are moved about six times as fast.

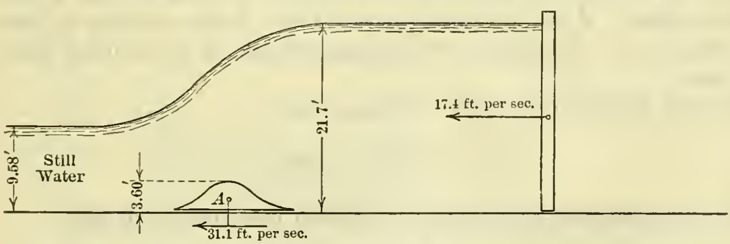

FIG. 3.—Same as Fig. 2, except that B is replaced by gate moving about half as fast.

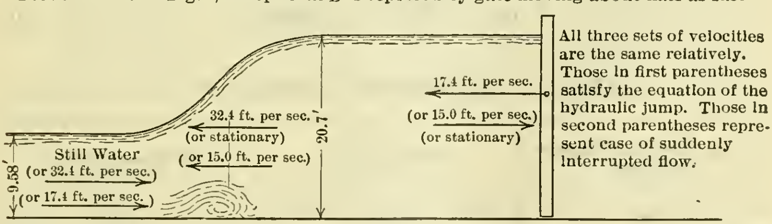

FIG. 4.—Same as Fig. 3, except that A is removed so that jump, instead of occuring without loss of head, contains the normal jump losses, the surface is not lifted so high, and the standing wave travels faster.

actually be considerable at this velocity. In Fig. 3, one of the dams is replaced by a gate; and, in Fig. 4, the other dam is removed, resulting in a case exactly similar to the suddenly interrupted canal flow described by the author.

Mr. Kennison.

All velocity being relative, the absolute velocities in Fig. 4 are also expressed relative to the velocity of the standing wave, illustrating the normal hydraulic jump, and also relative to the gate, illustrating the canal surge. These four figures are not necessary to show this relation, but they may prove interesting in a study of the hydraulic principles involved.

It is apparent, therefore, that to find a general expression (neglecting friction) for the resulting depth, D, in a channel of rectangular cross-section in which the water, flowing with depth, d, and velocity, v, is suddenly checked, it is merely necessary to take Professor Unwin's formula for the hydraulic jump,* which is in excellent agreement with experiment and is apparently based on sound theory, and substitutes for the velocity before the jump its value in terms of the difference in velocities before and after the jump. The result checks exactly with the equation deduced independently by the author. Since this is a cubic equation, it cannot be solved easily, except by trial. The following simple equations will probably be found more convenient. They are not mathematical equivalents of the Unwin quadratic equation for the hydraulic jump and the author's cubic equation for the canal surge, but, as shown by Table 1, for all reasonable uses, the error is well within the precision attainable in hydraulic computations of this nature. d is the depth, in feet, and v is the velocity, in feet per second, in a rectangular (frictionless) flume. D is the depth after the jump.

For the hydraulic jump or standing wave:

$$D = \frac{v\sqrt{d}}{4} - 0.45\,d \qquad (1)$$

For the receding wave caused by sudden interruption of flow:

$$D = \frac{v\sqrt{d}}{5} + 0.99\,d \qquad (2)$$

TABLE 1.—APPROXIMATE VALUES OF $D \div d$.

By the Unwin or Johnson Formulas.	By Equation (1).	By Equation (2).
1.20	1.18	1.21
1.40	1.39	1.41
1.60	1.60	1.60
2.00	2.00	1.97
4.00	4.03	......
6.00	6.05	......
10.00	10.07	......
20.00	20.10	......

* *Proceedings*, Am. Soc. C. E., for February, 1916, p. 292, Fig. 35; or *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 410.

IRVING P. CHURCH,* ASSOC. AM. SOC. C. E. (by letter).†—As regards the very interesting problem involved in this paper, on the surge produced in a nearly level, open canal of rectangular section, in which water is initially flowing with uniform velocity, when a vertical gate is suddenly dropped and completely closes the channel, the writer recalls no prior treatment in English, except as found on the last page of an article by Mr. Ford Kurtz.‡ In his treatment, however, in applying the method involving "change of momentum" Mr. Kurtz inadvertently used the mass of the flow per second of the water approaching the advancing surge and as yet unaffected by it, instead of the mass suffering impact per second, in forming his expression for the rate of change of momentum; that is (in his notation), he wrote $\frac{\gamma\, b\, h_1\, v_1}{g}$, instead of $\frac{\gamma\, b\, h_1}{g} \times \frac{l_1}{t}$. Had he used the latter expression, he would have arrived at a result identical with Mr. Johnson's Equation (1). Mr. Church.

Turning to French sources: Flamant§ gives the following demonstration (here modified for a channel of rectangular section and constant width, b, and with some of the notation of the present paper). See Fig. 5.

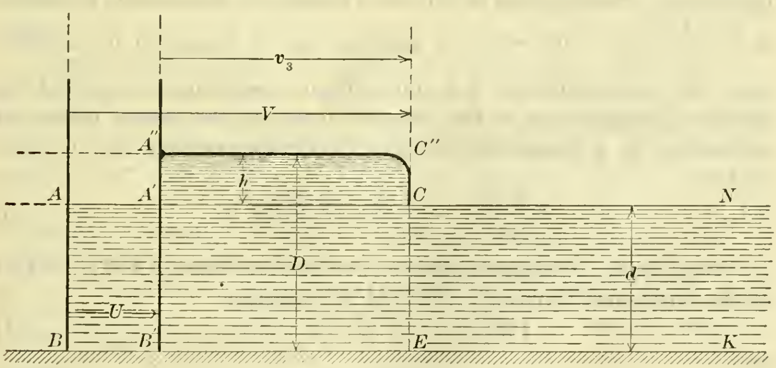

FIG. 5.

Let AB be a rigid vertical plate, or gate, entirely closing the end of a straight horizontal channel of rectangular section and constant width, b, which contains water at rest, extending indefinitely to the right, and of depth, d. The plate is at right angles to the sides of the channel. Let the plate now assume instantaneously a velocity of

* Ithaca, N. Y.

† Received by the Secretary, June 29th, 1916.

‡ "Application of Newton's Second Law of Motion to Certain Hydraulic Problems". *The Cornell Civil Engineer*, January, 1916. Published at Cornell University, Ithaca, N. Y.

§ "Hydraulique", p. 415, Second ed., Paris, 1900.

Mr. Church. U feet per second toward the right, this velocity being then maintained at constant value. The water near the plate acquires (in small installments) the same velocity, U, and is heaped up in front of it with a flat top and constant depth, D, the front edge, $C''C$, of this wave (wave-front) moving toward the right with some constant velocity, V. Let $D - d$, or the height of the wave, be denoted by h. If γ is the weight of a cubic unit of water, the total horizontal pressure (above atmospheric) between the plate and the raised water is $\frac{\gamma\, b\, D^2}{2}$; and, similarly, that between the vertical face, CE, of the water just under the wave front and the (as yet) stationary water on its right is $\frac{\gamma\, b\, d^2}{2}$.

Let us now trace the motion for the first second of time. At the end of this second the plate is at $A'\,B'$, having moved a distance $\overline{AA'} = U$, the wave front is at C, at a distance $\overline{AC} = V$, from AB, and the parallelopiped of water, $A''C''CEB'A'A''$ has a velocity, U (the water on the right being still at rest); while at the beginning of this second, the plate being at AB, this same mass of water formed the parallelopiped, $ACEBA$, and had a velocity of zero. The change of momentum brought about in this mass during the first second, therefore, is $\frac{\gamma\, V\, b\, d}{g}\,(U - 0)$, which is also the rate of change of momentum, since the time concerned is a unit. Hence, equating the sum of the horizontal components of the external forces to the rate of change of momentum in a horizontal direction (neglecting friction on the bed), we have

$$\frac{\gamma\, b\, D^2}{2} - \frac{\gamma\, b\, d^2}{2} = \frac{\gamma\, V\, b\, d}{g}\, U \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Water being incompressible, we have also: volume, $AA'B'B$ = that of the horizontal "lamina", $A''C''CA'A''$; whence

$$Ud = (V - U)\;(D - d) \quad \ldots\ldots\ldots\ldots\ldots (3)$$

or,

$$UD = V(D - d) \quad \ldots\ldots\ldots\ldots\ldots (3a)$$

that is, replacing $D - d$ by Flamant's symbol, h (height of wave), we may also write

$$Ud = (V - U)h \quad \ldots\ldots\ldots\ldots\ldots (3b)$$

and

$$UD = Vh \quad \ldots\ldots\ldots\ldots\ldots (3c)$$

Eliminating U by means of Equations (2) and (3b), and writing h for $D - d$, we may solve for V, obtaining

$$V = \sqrt{g\left[d + \frac{3}{2}\,h + \frac{1}{2} \times \frac{h^2}{d}\right]} \quad \ldots\ldots\ldots\ldots\ldots (4)$$

or, approximately, since the last term in the bracket is generally quite small compared with those preceding, Mr. Church.

$$V = \sqrt{g\left[d + \frac{3}{2}h\right]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4a)$$

or again, expanding $\left[1 + \frac{3}{2} \times \frac{h}{d}\right]^{\frac{1}{2}}$, and retaining only the first two terms of the converging series (that is, neglecting $\left(\frac{h}{d}\right)^2$ and higher powers as compared with the first two terms), we derive another approximate relation, *viz.*:

$$V = \left[1 + \frac{3}{4} \times \frac{h}{d}\right] \sqrt{g\,d} \ldots\ldots\ldots\ldots\ldots (4a)'$$

Flamant does not attempt to solve for the wave height, h, in terms of U and d, but is principally interested in the value of V, the velocity of wave propagation; but, if we substitute in Equation (2) the value of V derived from Equation ($3a$), there is obtained

$$\frac{D^2 - d^2}{2} = \frac{D\,d}{D - d} \times \frac{U^2}{g} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

a cubic in D, if D (and finally h, $= D - d$) is sought; U and d being given.

Leaving Flamant's demonstration, it is noted that, relatively to the moving plate, the still water on the right of CE has a velocity toward the plate (call this velocity v) equal to U; and, similarly, that the velocity (call it v_3) of the wave front, $C''CE$, relatively to the moving plate, is $A\ C$, that is, $V - U$, away from the plate. It follows, therefore, that in case the water in the open channel, with depth, d, has originally a velocity of v feet per second toward the left and the plate is suddenly dropped, so as to block completely the flow toward the left, and remains fixed in that position, the values of the wave-front velocity, v_3, and of D (or of wave height, h), become determinable by simply substituting v for U, and $v_3 + v$ for V, in the preceding equations. v_3, therefore, is the velocity of the wave front, or surge, and D is the depth of the (now motionless) water between the plate and the wave front. This conception, by which the solution of the surge problem may be based on that of the plate advancing against still water, is introduced by the French engineer, Bazin, in a report (to be referred to later) on the experimental investigation of both cases.

In this way, then, we obtain for the problem of the surge wave dealt with by Mr. Johnson,

$$\frac{D^2 - d^2}{2} = \frac{D\,d}{D - d} \times \frac{v^2}{g} \ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Mr. Church. (which checks the author's Equation (1)), and

$$v_3 = \sqrt{g\left[d + \frac{3}{2}\,h + \frac{1}{2} \times \frac{h^2}{d}\right]} - v \dots\dots\dots\dots (7)$$

In these equations, and also in all subsequent formulas, the author's notation is used, with the addition of $h = D - d$. We may also set down for this case the approximate relations (see Equations (4a) and (4a)′):

$$v_3 = \sqrt{g\left[d + \frac{3}{2}\,h\right]} - v \dots\dots\dots\dots (8)$$

and
$$v_3 = \left[1 + \frac{3}{4} \times \frac{h}{d}\right]\sqrt{g\,d} - v \dots\dots\dots\dots (9)$$

As regards solving separately for the height of surge, h, or $D - d$, we may write $v_3 + v$ for V, and v for U, in Flamant's Equation (2), combine with Equation (9), and then solve the resulting quadratic; whence, if $v\sqrt{\frac{d}{g}}$ be denoted by k, there results

$$h = \frac{1}{4}\left[\sqrt{16\,d^2 + 8\,k\,d + 9\,k^2} + 3\,k - 4\,d\right] \dots\dots (10)$$

as a fair approximation when h is small compared with d.

We have also from Equation (3b)

$$vd = v_3 h \dots\dots\dots\dots (10a)$$

In his report* to the French Academy of Sciences on an experimental investigation of the propagation of waves in open channels, Bazin gives the data and results of Bidone (1824) in the same field as well as Darcy's (1856). Bidone's experiments were performed on a very small scale, his channel being only about 2 ft. wide and about 40 ft. long in which to create and observe the wave phenomena; whereas Darcy and Bazin made use of, not only an experimental channel about 6.5 ft. wide and more than 1 000 ft. long, with depths of water of 2 ft. and less, but also of a straight reach of a navigation canal, some 3 000 ft. long and 30 ft. wide, with depths as great as 3 ft., as well as of a smaller basin 20 ft. wide.

Such being the fairly large scale on which the Darcy experiments were made, it has always seemed remarkable to the writer that Bidone's results should be quoted so frequently in American books on hydraulics, with little or no mention of Darcy's (in this field of wave motion, standing waves, etc.).

According to this report of Bazin's, Bidone derived the following relations from his experiments with surges going up stream and

* "Recherches Hydrauliques"; by Darcy and Bazin, Deuxième Partie, Paris, 1865.

caused by the abrupt closing of a transverse gate in moving water, channel rectangular, *viz.*: Mr. Church.

$$h = \frac{2\,d + h}{h} \times \frac{v_2}{2\,g} \qquad (11)$$

which may be written $h = \frac{v^2}{2\,g}\left[\frac{1}{2} + \sqrt{\frac{4\,g\,d}{v^2} + \frac{1}{4}}\right]$ ....(12)

and $$v_3 = \frac{v\,d}{h} \qquad (13)$$

As to the formulas based by Bazin on the Darcy experiments, let us first note that in 1844 J. Scott Russell presented, at the Fourteenth Meeting of the British Association for the Advancement of Science, an account of his interesting experiments on the "wave of translation" in still water. These were made on quite a small scale, in a channel of rectangular section, and led to the formula, $V = \sqrt{g(d + h)}$, for the velocity of the wave. (Compare with Flamant's Equation (4*a*).) This result was verified very satisfactorily by the Darcy experiments on the same phenomenon, these being made on a much larger scale. Bazin, therefore, adopted this formula, modified to suit the altered conditions, as a foundation for an expression for the velocity of wave propagation for the case now under discussion (sudden complete closing of a gate across a rectangular channel containing moving water). That is, he first writes

$$v_3 = \sqrt{g\,(d + h)} - v \qquad (14)$$

and then eliminates h by the aid of the relation,

$$h\,v_3 = v\,d \qquad (15)$$

see Equation (10*a*). The resulting cubic in v_3 can be factored, and yields one positive root, *viz.*:

$$v_3 = \sqrt{g\left(d + \frac{v^2}{4}\right)} - \frac{v}{2} \qquad (16)$$

But, experiment showing a somewhat larger value for h in terms of v_3 than as given by Equation (15), he modifies the algebraic relations on that basis and finally obtains, as fairly justified by experiment,

$$v_3 = \sqrt{\frac{v^2}{4} + g\,d} - \frac{2}{5}\,v \qquad (17)$$

and, as an average,

$$h = \frac{1.2\,v\,d}{v_3} \qquad (18)$$

As it may be of interest to compare the results obtained from these various formulas, let us take the data: $v = 4$ ft. per sec., and $d = 4$ ft.,

Mr. Church. to find both v_3 and h (that is, $D - d$). The results are shown in Table 2.

TABLE 2.

Equation from which derived.	h, in feet.	v_3, in feet per second.
Equation (6), Johnson	1.518	.....
(7) "	.....	10.53
(8)	.....	10.22
(9)	.....	10.56
(10)	1.52	.....
(12), Bidone	1.544	.....
(13) "	.....	10.39
(17), Bazin	.....	9.92
(18) "	1.93	.....

Bazin calls attention to an important fact which escaped the attention of Bidone: that the height of wave at the wave-front itself is somewhat greater than that of the portion of water behind. Bazin's formula seems to provide for this.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DISCUSSION ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.*

By Sanford E. Thompson, M. Am. Soc. C. E.

Sanford E. Thompson,† M. Am. Soc. C. E. (by letter).‡—The work of the Committee is the first investigation of earths and methods of tests of earths on a basis which is scientific and, at the same time, designed to form a foundation for practical conclusions. Undoubtedly, the work will be criticized by some as theoretical. When, however, we consider the present practice of basing all determinations of this character on judgment—a reliable guide where, and only where, it is sufficiently backed up by experience—the need of greater knowledge of facts, and then of more definite rules, based on tests and, if possible, on formulas, is evident. The fact that we find scarcely two soils which are alike is no reason for adhering permanently to rule-of-thumb procedure, but is a condition which shows the necessity for a thorough and far-reaching study. In connection with construction management, the writer has found it necessary to go into the study of the rules to a limited extent, far enough, however, to appreciate the size of the problem and the difficulties to be encountered, and, at the same time, to appreciate the possibility of a more rational and scientific treatment than has hitherto been considered possible. Mr. Thompson.

Thus far the Committee has attempted to study simply the fundamental principles. It is to be hoped that its members will have the patience and receive the encouragement needed for a continued prosecution of the work.

* Discussion of Progress Report of the Special Committee to Codify Present Practice on the Bearing Value of Soils for Foundations, etc., for 1915, continued from May, 1916, *Proceedings*.

† Newton Highlands, Mass.

‡ Received by the Secretary, May 31st, 1916.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DISCUSSION ON FLOODS AND FLOOD PREVENTION*

By Messrs. Gerard H. Matthes, H. K. Barrows, N. C. Grover, and E. C. LaRue.

Gerard H. Matthes,† M. Am. Soc. C. E. (by letter).‡—The writer endorses very heartily the recommendation contained in the Progress Report of the Special Committee on Floods and Flood Prevention, urging the establishment and unification of systematic rainfall, run-off, and flood observations covering the entire United States in far greater detail than has yet been attempted; also, the recommendation contained in the Minority Report, urging the creation of a special agency, supported by adequate appropriations, for carrying on this work. Our knowledge of floods in general is sorely in need of systematic development; the recommendations referred to indicate the first logical step to that end. Mr. Matthes.

There is a crying need for carefully compiled chronological flood data showing dates of occurrence, flood heights, distribution and quantities of rainfall, rates of run-off, and notes as to what tributaries were directly responsible for the formation of flood crests, for all rivers of importance, and including also the lesser streams which, owing to geographical or commercial conditions, present special flood problems. The writer believes that the Committee can render the Profession no greater service than by outlining a plan of procedure for collecting, collating, and publishing such facts systematically.

A review of available river stage, stream flow, and rainfall data reveals a deplorable lack of accurate statistics pertaining to either floods or to extreme low-water conditions. Yet, these two subjects are

* Discussion of Progress Report of the Special Committee on Floods and Flood Prevention for 1915, continued from May, 1916, *Proceedings*.

† Dayton, Ohio.

‡ Received by the Secretary, May 13th, 1916.

Mr. Matthes. of more economic importance than any others pertaining to the regimen of streams. Floods are at present attracting unusual interest; low-water stages and droughts will probably become of more and more interest as time goes on. As matters now stand, the practising engineer, who is required to study and report on means for abating flood damage in a given locality, finds three distinct classes of information at his command:

1.—River stage, stream flow, and rainfall observations, made under the direction of Federal and State bureaus, and of certain corporations, all of which observations are more or less readily obtained in printed form. In this class belong also miscellaneous data published in technical journals.

2.—Data pertaining to floods which antedate the periods covered by existing records, and concerning which but little has been published in technical publications.

3.—High-water marks.

Each class of data possesses limitations of its own, as will appear from the following considerations. Data of Class 1 are generally regarded as affording the most reliable information. Unfortunately, river stage records are available for comparatively few streams, and rainfall records are obtained at illogically distributed points. The average river stage record does not cover more than 20 years, a period entirely inadequate for studying floods with reference to their frequency. Even 40-year records, of which a number are in existence, are inconclusive in this respect, because they contain rarely more than one extraordinary flood. The principal short-coming of such records, however, is that they were obtained primarily to supply information of a general nature, and not to afford specific information regarding floods. This fault has been recognized, and is being remedied. The United States Geological Survey and the United States Weather Bureau, in recent years, have instructed their observers to record the maximum or crest stage of each flood, and in case of flood stages caused by back-water from ice jams, to make notes to this effect. Previous to this there was no definite practice, some observers reporting readings taken at the customary hour, others reporting the crest stage without stating in all instances the time of its passing. Others took sufficient interest to obtain a series of readings during a flood, but the Bureau, in publishing the record, contented itself with averaging them and printing the meaningless figure thus obtained as representing the average gauge height for the day. This practice is still in vogue in some quarters. Many flood heights published by the Signal Service and the Weather Bureau in their earlier reports, on investigation, have proved to be distortions caused by ice jams, and are not to be taken as indications of flood discharge. Failure on

the part of engineers to investigate and check up such records before using them has resulted in the indiscriminate use of observations which are not comparable. Some engineers believe that inaccuracies and inconsistencies of the kind referred to are not likely to affect their conclusions one way or another. Others, unaware of the defects, have taken the records for gospel truth, and with painstaking care have made them the basis of mathematical and graphical studies, assigning to them a value which is wholly unwarranted. Mr. Matthes.

There is an urgent need for a complete revision of all published river stage records and stream flow data, in so far as they relate to floods. The importance of this matter cannot be over-emphasized. A revision of this kind was undertaken some time ago by the Water Supply Commission of Pennsylvania for the streams of that State, as a result of which many of the theretofore published maximum rates of run-off have been materially increased. The writer's studies in this field lead him to believe that probably 50% of the maximum run-off figures published by various authorities, among them the much quoted ones of the late Emil Kuichling, M. Am. Soc. C. E., do not represent crest stages at all, but are based on unscientific observations of the kind just alluded to, and are not even reliable 24-hour averages. The seriousness of this state of affairs is not generally recognized, and deserves the earnest attention of the Committee.

It is generally recognized that the number of river and rainfall stations should be greatly increased. Co-operation between the Federal Government and individual States has given good results in some cases. As an instance of what may be accomplished by a State acting independently, may be cited Pennsylvania, which in 1907 took over from the U. S. Geological Survey a score of river stations, and has increased this number until at present observations are received from more than 100 stations.

The development of our knowledge of floods by continuing existing records and starting new ones is only one phase of the subject; the other phase is to gain knowledge concerning floods which took place before regular observations were begun. This involves the collecting and collating of data of Class 2.

Much valuable information concerning floods, their heights and causes, is obtainable by consulting the files of historical societies, public and private libraries, newspapers, old diaries, private records, and unpublished matter of various kinds. Extensive researches by the writer in this field have taught him that there is a vast quantity of good material awaiting him who will take the trouble to unearth it. Such material, when properly interpreted, and utilized with care, so as to eliminate erroneous data, can be made of great value, covering as it usually does the major portion of the history of any river, in point of time. Obviously, a 150-year record, consisting of fairly complete

Mr. Matthes. data relating to great floods, will be of much greater value in determining a future flood control policy, than a 40-year record of daily gauge heights obtained on the same stream by a $5 per month uneducated observer.

Some attempts have been made to compile flood records for a few of the more important streams of the United States, the data extending back to the earliest days of settlement. The reason more has not been done along this line is that it has not been made anybody's business to attend to it, and because, also, of a certain amount of prejudice generally prevailing against the use of non-technical data. Federal and State bureaus have made little effort to collect information of this kind, principally for lack of appropriations, and partly because of inertia to be overcome in stepping out of the beaten paths of regular routine. The nearest approach to work of this kind was undertaken by the Water Resources Branch of the U. S. Geological Survey, when, in Water Supply Papers Nos. 96, 147, and 162, it published accounts of destructive floods during the years, 1903, 1904, and 1905, respectively, including many references to early floods. The Weather Bureau has also listed early floods for a few streams. Without doubt, both these bureaus possess a large quantity of material, which, if carefully checked and amplified, would become most valuable contributions to flood literature. In its present condition, such information lies dormant, and is of no benefit to the Profession.

Reverting next to Class 3, High-water marks, it appears that mankind, since the earliest times, has manifested a keen interest in the destructive action of rivers. Before the days of regular observations, it had become a frequent practice to perpetuate by permanent marks the height attained by great floods. The extent to which this has been done along the streams in the early settled portions of the United States is remarkable, as will be testified to by those who have had occasion to make systematic search for such marks. Here, as elsewhere, in dealing with information pertaining to floods, it is of the utmost importance to guard against errors, and it is necessary to check the marks, not only against each other, but by comparing the information which they furnish with that obtained from accounts and other data. When made on factories, mills, pumping stations, and bridges by the mechanics, millers, or engineers thereof, such marks, as a rule, are well recorded and reliable.

The present condition of our knowledge of floods is such that few practising engineers are placed in a position where they can utilize to advantage any one of the three classes of flood data here discussed. Lack of facilities, and lack of access to old files or other sources of information stand in the way, and frequently the problem must be solved by guesswork where reliable data might have been used had it been available in conveniently accessible form. It should be made the

province of Federal or State bureaus to remedy this condition. To do so calls for considerable research and academic work, neither of which should devolve on the practising engineer, or become a source of expense to his client. Mr. Matthes.

In conclusion, the writer wishes to state that it is to be regretted that the duties of the Committee were limited to the investigation of flood matters only; they should have included an investigation of low-water conditions. The subjects are closely related, and the methods which may be utilized for systematizing the knowledge concerning the one could without doubt be made to apply to the other. It is to be hoped that this important feature will not be overlooked when an agency is created such as suggested in the Minority Report. Such an agency could handle advantageously matters relating to low as well as to high water. Great floods have left their imprints where they may be seen for generations to come; but low-water stages have left no such records behind them. Unless an effort is made soon to trace back the happenings of this class which took place in years past, it will become increasingly difficult to glean much on this important subject.

H. K. Barrows,* M. Am. Soc. C. E. (by letter).†—The writer has been much interested in the report of the Special Committee on Floods and Flood Prevention, as presented at the Annual Meeting on January 19th, 1916, the Minority Report by Mr. Knowles submitted therewith, and the subsequent discussions by Messrs. Eakin, Hill, Leighton, Grant, and Groat. Mr. Barrows.

The writer is in general accord with the suggestions made by Mr. Knowles in the way of amplifying the report of the Committee, and particularly with regard to a special National agency for making general studies of the subject of floods and flood prevention and procuring systematic and comprehensive data necessary for carrying on such studies.

Mr. Grant states the situation exactly when he says that data are not now available with which to design intelligently and economically the works to carry out the purposes contemplated by the enormous appropriations for river regulation and water conservation which have been urged continually before Congress.

The Water Resources Branch of the United States Geological Survey is the only Government Bureau carrying on systematic river measurements, and, up to the present time, its appropriation for this purpose has been very limited. The entire amount appropriated annually for gauging purposes is only $150 000, which is only partly available for river measurements and must also be used for the administrative and other expenses of this Bureau. This sum is absurdly small, and, in the writer's judgment, the Committee could well make

* Boston, Mass.

† Received by the Secretary, May 18th, 1916.

Mr. Barrows. a specific recommendation to aid in the advancement of our knowledge relative to floods and other river conditions by urging strongly upon Congress that the amount of this appropriation be increased very materially. When the great value of such data is considered from the point of view, not only of flood investigation, but of water power and water supply in general, it would seem that the annual appropriation for this purpose should be at least $500 000.

The discussion of the use of levees in flood prevention brings out clearly the fact that on large interstate streams a comprehensive scheme for the entire river should be developed, as the use of levees often means a change in hydraulic gradient at flood times extending many miles up stream from the point of the works.

Although the necessity for the use of levees in the lower Mississippi seems to have been proved, the writer is not greatly impressed by the figure of 1 365 000 000 000 cu. ft. cited by the Committee as the storage capacity of levees on the Mississippi between the mouths of the Ohio and Red Rivers. Although the figures in themselves are large, it must be kept in mind that the effect of storage capacity on a stream depends on the tributary drainage area as well as the quantity of storage. The total drainage area of the Mississippi above the Red River is about 1 259 000 sq. miles, and the 1 365 000 000 000 cu. ft. of storage capacity between levees corresponds to a little less than ½ in. in depth over this drainage area, a quantity which obviously of itself is not of great importance in retarding flood waters. Considering only the drainage area of about 329 000 sq. miles between the Ohio and Red Rivers, the storage in the levees would be only about 1.8 in. in depth over this area, or not enough to affect greatly the run-off of even this smaller district. The writer agrees with Mr. Knowles in this respect, that the potential storage over the surrounding country and overflowed land is much greater than the volume confined between levees. The important function of the levees is in increasing the carrying capacity of the channel and confining the flow, rather than in storage.

The recent report of the Miami Conservancy District is an excellent example of an intelligent solution of the flood problem on one stream wholly within one State. For the larger or more extended problems involving interstate streams, obviously, studies should be made by some National agency, and the writer believes that the Committee might well take a more positive stand on this matter and urge the creation of such an agency, supported by an adequate appropriation.

Mr. Grover. N. C. Grover,* M. Am. Soc. C. E. (by letter).†—With the occupancy of the river banks and bottom lands by cities, towns, and farms, the damages caused by floods have increased, until the problem of

* Washington, D. C.

† Received by the Secretary, May 22d, 1916.

their control has become of National importance. Recent disastrous floods have led to the appointment of municipal, State, and Federal commissions for the study of local conditions or special phases of the flood problem. The appointment of a Special Committee of the American Society of Civil Engineers for study and report on floods and their prevention is a manifestation of the interest in and importance of the problem. Mr. Grover.

The duty of the Society to make a broad, comprehensive, and unbiased study of the flood situation having been recognized by the appointment of this Committee, a heavy burden of responsibility rests on the membership in its attempt to guide the various governmental organizations to an adequate solution of the flood problems. The Society must now see to it that this responsibility is discharged properly and adequately, and its final action should be sound in principle, broad in scope, and definite in application, so that it may serve as a basis for safe, adequate, and unbiased legislation.

At the present time flood work is scattered through many organizations. Several States and municipalities have investigated local flood problems. The United States Weather Bureau has developed an efficient service for flood warnings on the principal rivers of the country, and has collected many valuable records of river stage. The United States Geological Survey has collected many records of flood discharge, as a part of its work in systematic stream gauging, and has made topographic maps of river basins and of reservoir sites that are invaluable in a study of floods and their control. The Corps of Engineers, United States Army, has charge of all construction on navigable streams and, incidentally, has collected much information relative to floods on such streams. Each of these various organizations has conducted its work in full recognition of the work of the others, but with little actual co-operation. There has been, however, no organization to undertake a broad, comprehensive study of the whole problem.

Flood problems range in complexity and importance from those surrounding a local flood affecting only a small area in a single State to those involving the welfare of the people of several States, or even important international questions. Present methods of treatment are almost invariably local and piecemeal, without proper consideration of the general situation, of possible antagonistic results of different projects and methods, or of the possibility of disastrous effects of projects on unimproved parts of the river system. They do not bring about, therefore, that general orderly improvement in the condition of river stage and erosion that should result from correct and adequate methods of treatment. The co-ordination of projects according to sound and harmonious methods should also eliminate useless efforts and waste, and secure the desired results at a minimum cost.

Mr. Grover. The elements of a general programme for flood control, on which recommendations should be made in the report of the Society, are:

1.—The development by appropriate research of a fuller knowledge of the laws of river hydraulics and physiographic processes which is prerequisite to a sound practice of river control;

2.—The expansion and improvement of methods of control, on the basis of fuller scientific knowledge, including, possibly, vertical as well as horizontal control of streams, with consequent reduction of necessary levee heights, contraction of levee systems, and elimination of harmful reactions between different projects and methods;

3.—The co-ordination and standardization of the collection of data as to quantity of water, débris in transit, and consequent adjustment of grades and channel forms;

4.—Surveys necessary as a basis for the design of regulatory works, estimates of cost, and of the effects of such works;

5.—Agencies to be used in collecting data and in building and operating the necessary structures;

6.—Division of cost of such structures among the organizations co-operating, or the parties benefited;

7.—Possible combination of flood control, navigation, water power, drainage, and irrigation, under the same general regulative programme;

8.—The organization of a special Federal bureau equipped to execute a full programme of river improvement.

The Progress Report of the majority of the Special Committee on Floods and Flood Prevention, which was presented at the Annual Meeting, was discussed by the minority as a Progress Report. The Chairman, later, requested that the report be considered as the Final Report of the Committee. It is unsatisfactory to the writer, however, either as a progress or a final report, largely because of its apparent lack of clear insight into several important phases of the flood question and of definite suggestions or recommendations. It calls attention only to the need for additional and standardized physical data, and discusses certain suggested methods of flood control in a manner that favors those now in vogue. It ignores the necessity for developing a science of river hydraulics and improving the practice of river control, for active co-operation of agencies in collecting data, in building and operating structures, and in dividing costs, and for the co-ordination of all flood work under one directing head and in one programme. The Minority Report is a great improvement on that of the majority, in many respects, but does not accomplish the purposes, as they appear to the writer, of a final report of a committee of this Society.

It is believed, therefore, that both the Majority and Minority Reports should be received, the Committee discharged, and a new committee appointed to consider again the important problems involved, in the hope that a more comprehensive and definite report may serve as a basis for the final action of this Society on the important problems involved in the flood situation. Mr. Grover.

E. C. LaRue,* Assoc. M. Am. Soc. C. E. (by letter).†—The Committee has wisely called attention to the paucity of data available for studies of flood control, but it does not seem consistent in the same report to draw definite conclusions with respect to the relative merits of the various methods of flood control and flood prevention. The writer agrees with the statement of Mr. Knowles, on page 2783,‡ that the Committee has given a single view "on controversial subjects on which it must be recognized that much more information can and should be obtained". Mr. LaRue.

For example, on page 2781,‡ the Committee says:

"As you proceed down stream the influence of reservoirs on flood prevention rapidly diminishes, and the influence of levees correspondingly increases in importance as a method of flood protection. On the lower alluvial reaches of long rivers, such as the Mississippi and Colorado, they afford the only sure means of flood control."

This statement is not correct when applied to the Colorado River. The writer has recently completed a report, entitled, "The Colorado River and its Utilization",§ in which it is shown that reservoirs may prove an effective means of preventing floods on the lower Colorado. The area of the Colorado River Basin is 244 000 sq. miles. The precipitation and run-off from the lower half of the basin is small compared with that on the upper half. At Yuma, Ariz., 92% of the annual run-off is contributed by that part of the drainage basin lying above the Utah-Arizona line, which is 700 miles above Yuma. Green and Grand Rivers, which unite to form the Colorado in southeastern Utah, drain 70 300 sq. miles, which is only 28.8% of the Colorado River Basin; yet these rivers contribute 76% of the water that passes Yuma. A dam constructed to raise the water level 270 ft., immediately below the junction of Green and Grand Rivers, would create a reservoir having a storage capacity of 8 600 000 acre-ft. On June 14th, 1914, a maximum flood of 137 000 sec-ft. occurred at Yuma. The crest of this flood at the junction of Green and Grand Rivers was 120 000 sec-ft., and passed that point on June 3d. By utilizing the reservoir site at the junction of the Green and Grand, this flood of 137 000 sec-ft. at Yuma could have been reduced to 17 000 sec-ft.

* Salt Lake City, Utah.

† Received by the Secretary, May 23d, 1916.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915.

§ U. S. Geol. Survey, Water-Supply Paper 395.

Mr. LaRue. This reservoir site is 880 miles by river above Yuma, and about 1 000 miles above the mouth of the Colorado. It is clear, therefore, that in this basin, at least, the influence of reservoirs on flood prevention does not rapidly diminish down stream. The Colorado tends to overflow its banks in the vicinity of Yuma at the 25-ft. stage on the gauge. The average carrying capacity of the channel at the 25-ft. stage is about 50 000 sec-ft. The writer, therefore, believes that nearly all overflow can be prevented on the lower Colorado, and that the flow can be regulated to meet the demand for water for irrigation, if the reservoir site at the junction of Green and Grand Rivers is utilized, and detention basins and reservoirs are constructed on the San Juan and Gila Rivers for the purpose of reducing the violent floods that happen occasionally on these tributaries. On the lower reaches of the Colorado the river bed is being slowly built up, and at the present time the river is flowing on the highest ridge of its delta. When the flow of the Colorado is regulated, the cost of constructing levees and bank revetments will be reduced to a minimum. It is probable, therefore, that the final plan for the control and prevention of floods on the Colorado will involve the construction of reservoirs, detention basins, and levees.

As to the proper methods of controlling and preventing floods, there are nearly as many opinions as there are engineers engaged in the study of the problem. Each drainage basin or river system presents a different problem, and perhaps this fact accounts for the divergence in the opinions expressed by engineers as to the effectiveness of the respective methods of flood control and flood prevention. The opinion of each engineer will probably be influenced largely by conditions in drainage basins with which he is familiar.

The Committee, no doubt, did not intend its report to be interpreted as an invitation to engineers to discuss the relative merits of reservoirs *versus* levees as a means of flood control, but the discussions that have been published indicate a tendency in this direction. To the writer it seems no more consistent for engineers to discuss the relative merits of the various methods of flood control without confining their discussions to conditions in a particular basin than it would be for two engineers to debate the applicability of the Cippoletti weir *versus* the current meter as a means of measuring water, without agreement as to the quantity of water to be measured and the conditions controlling such measurement. One engineer, having in mind the measurement of streams in which the maximum discharge does not exceed 10 sec-ft., might advocate the use of the Cippoletti weir; the other, having in mind the measurement of the flow of the Mississippi at New Orleans, might as strongly advocate the use of the current meter.

When adequate data are obtained, reports will be prepared presenting plans for the control of floods in particular drainage basins.

Mr. LaRue.

Discussion of such reports will be of great value, in that it will concentrate the attention of engineers on specific problems. With this concentration of effort, in solving one problem at a time with but one set of conditions, no doubt most engineers will come to agreement, and possibly all will agree that under certain conditions a reservoir may serve more than one purpose; that in some drainage areas detention basins will solve the problem; that in others reservoirs must be constructed; and that on long rivers it may be necessary to construct check dams, detention basins, reservoirs, and levees.

So far as the problem of flood control and flood prevention is concerned, it would seem that the most valuable service that can be performed by the Engineering Profession at present is that of urging* the establishment of a "special agency, supported by adequate appropriations, for the purpose of studying stream regulation in its largest sense, and under whose direction all data shall be collated, according to uniform standards and systems, so that appropriate development of the science shall be made".

* *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2787.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

DISCUSSION ON MATERIALS FOR ROAD CONSTRUCTION AND ON STANDARDS FOR THEIR TEST AND USE*

By Messrs. P. E. Green, Calvin Tomkins, H. S. Mattimore, J. H. MacDonald, W. W. Crosby, T. J. McGovern, Edward E. Reed, R. A. Meeker, A. N. Johnson, Clark R. Mandigo, K. H. Talbot, William M. Kinney, J. C. Bentley, P. H. Wilson, George C. Warren, E. H. Thomes, Prévost Hubbard, W. H. Connell, William W. C. Perkins, J. E. Myers, H. B. Drowne, Philip P. Sharples, J. W. Howard, H. W. Durham, and R. A. MacGregor.

BROKEN STONE, SLAG, AND GRAVEL ROADWAYS.

P. E. Green,† M. Am. Soc. C. E. (by letter).‡—The writer has read with great interest the semi-final report of the Committee, and has been impressed with the fact that his experience does not coincide with many of the statements contained therein. Mr. Green.

The Committee states:

"It believes that many of the questions affecting the selection or use of these materials can only be solved by a better knowledge of their characteristics or qualities and more complete records along uniform lines of their behavior in use."

This is a commonplace statement which cannot be too often reiterated. It seems unfortunate that in a report of a Committee it is

* This is a discussion of the Progress Report of the Special Committee on Materials for Road Construction and on Standards for Their Test and Use for 1915, presented to the Annual Meeting, January 19th, 1916.

† Chicago, Ill.

‡ Received by the Secretary, January 3d, 1916.

Mr. Green. not practicable to include all the evidence submitted to it from which it drew its conclusions, as some of the statements in the report will undoubtedly be at variance with the experience of many engineers.

To take the report up in detail:

Under the heading "Broken Stone and Slag Roadways" the Committee states:

"For a water-bound broken-stone roadway, the void filler should be clean stone screenings or sand, and the use of clay should be avoided."

Under the heading "Gravel Roadways" it states:

"With gravels such as quartz, the cementation of which is extremely low, a highly cementitious void filler is desirable, and a moderate quantity of clay in sand used for filling the interstices of water-bound gravel surfacing may be advantageous where the water and frost action on the roadway surfacing is not too severe."

These two statements are at variance with each other. Very frequently, the character of stone used in broken-stone roadways is of a kind in which the cementation value is extremely low, and it is just as desirable for the material of such a road to have a void filler of a highly cementitious character as for a gravel road. If a moderate quantity of clay is advisable for the gravel road, it is certainly advisable for the broken-stone road.

When the writer was employed by the City of Chicago, some years ago, the City was building and had built several hundred miles of water-bound macadam, the wearing surface of which consisted of crushed Wisconsin granite. The cementitious value of this granite is exceedingly low, and the engineers were using and had used for many years a binder referred to as "bonding gravel". The writer has never seen an analysis of this material, but he believes from observation and close examination that it is composed of about 30% clay and 70% sand. He has never seen a better bonding material. The wearing surface, after having been thoroughly dried out, was almost as smooth as an asphalt pavement, and such highways withstood exceedingly well the traffic of that time, which, of course, consisted largely of horse-drawn vehicles.

The question of whether a binder is affected seriously by water and frost action relates only partly to the material used. It is very largely a matter of drainage and maintenance, and if these, which the writer regards as the most important features of any highway, are properly taken care of, so that water will not stand on the road, there will be little disturbance by frost action. The trouble with the wearing surface of a broken-stone or gravel road comes from the picking up or raveling of the stone composing the surface, and any material which tends to bind this tightly will improve it. The writer maintains that the report of the Committee should be modified in this particular.

A further statement of the Committee is as follows: Mr. Green.

"The Committee is of the opinion that uncarpeted roadways should be used only for light traffic."

It is believed that this is an improper sentence to put in a report of this character. The point may be a technical one, but the terms "light", "medium", and "heavy" traffic are exceedingly relative and elastic. What is light traffic in one section is heavy traffic in another, and such an indefinite term should not be used in a report of this kind.

Calvin Tomkins,* Assoc. Am. Soc. C. E. (by letter).†—Too exclusive reliance on laboratory tests of macadam stones should be avoided, and more attention should be given to the actual results obtained in practice, that is, to the wearing qualities of materials in roads. Mr. Tomkins.

Laboratory tests indicate relative hardness and toughness under laboratory conditions, and also cementing qualities. They do not and cannot show the resultant interactions of these qualities on each other, as developed by time, traffic, and the elements in the roadbed.

The cementing qualities are inversely related to the other qualities, and, under some conditions of road construction and use, merit in one set of qualities may be disadvantageous under others.

Because laboratory tests are new, and because we do not wish to be considered old-fashioned and under the rule-of-thumb, we are prone to consider them as the essence of good practice instead of as useful checks on practice.

By too generally specifying the use of special kinds of stones, it is very easy to create a monopoly price locally. In New York this result has been reached as regards the use of trap rock.

Expression of a preference, subject to the discretion of the engineer in charge, if monopoly exactions are demanded, will prevent extortion.

Very interesting comparative bids and tests are in evidence showing the persuasive influence of opening up specifications in this manner. Even when the engineer wants one kind of stone and intends to use no other, he can obtain it more cheaply by liberalizing his specifications. A good engineer should be a good purchasing agent, as well as a specifier.

H. S. Mattimore,‡ Assoc. M. Am. Soc. C. E.—Under the heading "Broken Stone and Slag Roadways", page 2723,§ the sixth paragraph reads: Mr. Mattimore.

"For a water-bound broken-stone roadway, the void filler should be clean stone screenings or sand, and the use of clay should be avoided. A proportion of fine mineral material, between certain maximum and minimum sizes, which proportion and sizes will depend largely on the character of the materials used, is desirable."

* New York City.

† Received by the Secretary, April 10th, 1916.

‡ Albany, N. Y.

§ *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Mattimore. It is assumed, from this paragraph, that the material used for the top of the void filler will have to act as a binder. If such is the intention, sand should be excluded. Average sand has absolutely no binding power. The speaker would suggest changing the expression "clean stone screenings" to "stone screenings", as "clean stone screenings" is likely to be interpreted as stone screenings free from dust, which is the real binder.

On page 2724,* it is advised, where a cementitious material is to be used, that the bottom of the voids be filled with some non-cementitious material or sand.

The speaker has seen this method followed when a non-cementitious material had to be used for the sake of economy. It was only used as a filler in portions of the top course, and should not be recommended. In fact, "water-bound construction" should aim at puddling and binding as much of the top course as possible. This necessitates a cementitious filler for the entire top course and by no means the use of sand, as it is impracticable to compact a course of stone filled with sand.

Under the stone test, there is a recommendation for cementation of rock slags and gravel powders. The speaker objects very strongly to the adoption of this test. The New York State Highway Department conducted some 500 tests on the cementing value of rocks, and the results did not agree with the practical conditions in the field.

Some of these results show that with gneisses and other quartz rocks, the cementing value was high, which is not the case in practice.

This condition is not only shown in the report of the New York State Highway Department, but the speaker has the results of some tests, which indicate a very high value for sandstone also; whereas, it is known that such results cannot be obtained in practice. Engineers have tried it, in some instances in New York State, and found, to their sorrow, that it could not be done.

Tests of crushing strength are rather expensive, and do not seem to be necessary. The speaker has consulted some figures on the strength per square inch of a great many of the common road-building rocks, and finds that the strength of porous stone which would not be considered for use in highway building, is much higher than any traffic load which could be put on such roads with a large factor of safety.

The speaker also believes that the crushing value of the rock itself is not indicative of the crushing value of the crushed stone which has been subject to stresses and developed lines of weakness during the crushing.

The speaker has run a few abrasion tests on gravel, in the stone abrasion machine, but the results were not satisfactory when run in the same way as stone.

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* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Mattimore.

Some tests have been made in Ohio and Illinois by placing a charge of shot in the machine with the gravel, and the speaker suggests that this matter be taken into consideration by the Committee.

Mr. MacDonald.

J. H. MacDonald,* Esq.—The following paragraph is found at the top of page 2724:

"For water-bound roadways of some limestones or of some slags, it will be advisable wherever practicable to use for one-half the void filler a non-cementitious material such as clean sand with the other half of the finer particles of the material itself."

It is natural to conclude that the Committee, in having to arrange for this large subject, found it very difficult to give an analysis of exactly what was in the minds of its several members when it condensed this report. Hence, it would be interesting to know what was the thought of the Committee in allowing sand to be used as a substitute for stone dust in the building of a water-bound macadam road. Was it a question of economy or of availability; or what were the relative merits to be considered as between the two materials used as a binder? It is a question, in the speaker's mind, whether, if the Committee, in bonding a water-bound road, had access to all the dust that was necessary, at the same price, would have recommended sand at all.

It is understood that the Committee recommends definitely the use of sand in "some limestones and some slags", but why? Is it to put additional wear in the road, or for cementitious purposes?

Had the Committee in mind the general use of sand as a bonding material with trap rock, or with the granites, or with other stones—sandstone, as has been mentioned—or was it the intention to confine it to "some limestones and some slags"?

When water is added to limestone, a chemical change takes place; that is, there is a combination instead of a mixture. There is a wide difference between the terms "mixing" and "combining"; for instance, water and sand may be mixed, but each will retain its original composition, and there will be no combination. On the other hand, if water and lime are mixed, a chemical combination is effected. The chemical change, which would make a mortar of the sand, would be advantageous, but the speaker cannot understand why sand mixed with trap rock is considered desirable. Sand, in such a case, will simply act as a wedge, not as a binding material.

In making this criticism, the speaker had in mind the practice in a certain State where, in each course, earth (subsoil) is used as a binder, and it had seemed to him that the limestone construction would furnish sufficient bond by attrition, without introducing any earth, thereby furnishing an invitation to moisture and frost. The

* New Haven, Conn.

Mr. MacDonald. speaker has never in all his practice used sand in the construction of a water-bound macadam road.

One of the difficulties with which the Committee has had to contend is the wide scope it has had to consider in this matter. It has been circumscribed both for time and for an opportunity to explain fully the meaning of various parts of the report. The speaker is of the opinion that the farther we get away from the making of a specification a textbook, the farther we will be from the solution of this great problem of highway construction. Every specification should be a textbook, and should be drawn so that it will not be a technical mystery to the contractor, and will speak for itself without having to refer to the engineer for explanations. It should be so clear that the contractor or any other man could "read as he runs".

In reference to the method of using trap rock screenings, a comparison of the relative merits of different water-bound macadam roads in Connecticut will be instructive. Some of these roads have been constructed from 16 to 18 years, some even 20 years, and are in good condition and very little broken. These roads have stood up well and have given good service, because the methods used in their construction, with reference to the binder and also the mixed stone, have been good.

Mr. Crosby. W. W. Crosby,* M. Am. Soc. C. E.—Mr. MacDonald seems to have misunderstood to some extent the paragraph on page 2724† of the report to which he refers in his discussion. The Committee meant exactly what it stated in this report, that is, with "limestones" and "some slags, it will be advisable * * * to use * * * a non-cementitious material such as clean sand", in bonding the macadam. The Committee did not recommend the use of sand in connection with trap rocks or sandstones. In the preceding paragraph in the report, the Committee deprecated the use of clay, and inferentially of earthy material, in any case, as will be seen by reference to that paragraph. The speaker might state, for the sake of further explanation, that the use of sand with limestone or some slags is recommended in order to reduce the ordinary difficulties of bonding such a macadam caused by the tendency of the wet limestone or slag screenings to stick to the wheels of the roller. A non-cementitious sand when used will offset this tendency and permit the voids to be properly filled, without detriment, if not without actual improvement in some cases, to the results secured.

Mr. McGovern. T. J. McGovern,‡ Esq.—There seems to be quite a difference of opinion as to whether sand, clay, or loam is the best. In a road, not quite 4 miles long, built by the speaker for Mercer County, New Jersey,

* Baltimore, Md.

† *Proceedings*, Am. Soc. C. E., for December, 1915.

‡ Trenton, N. J

mud was used as a binder, and also clay; and then gravel and sand were used. After the road was completed, the speaker could not see any difference in any part of the surface. That road has been in use about 4 years. Mr. McGovern.

The City of Trenton, N. J., builds roads of broken stone without any binder, and the roller is not used. The speaker thinks those streets are just as good with a binder of sand, clay, mud, or anything else, as they would be under any circumstance.

At one time, Mr. Frank Appell, Engineer for Mercer County, New Jersey, drew up a set of specifications for using trap-rock screenings, and built three different roads with that material. On two of the roads the trap-rock screenings were taken out because it was said that the road raveled and went to pieces.

The speaker is of the opinion that the rolling did not make any difference. The material was just thrown down, as is done in Trenton, without rolling or anything else, and the roads have been used for more than 10 years.

If a road is to be constructed with 8 in. of stone, it does not make any difference whether a 2½-in. layer is placed on the bottom, and a 1½-in. layer on the top, and screenings on that, or whether the several sizes are all mixed together, or whether a 1-in. layer is placed on the bottom. All the material is there, and the horses, wagons, and automobiles will do the rest.

EDWARD E. REED,* ESQ.—The speaker, who lives near Trenton, N. J., takes issue with Mr. McGovern regarding the streets of that city. In reference to the method of repairing those streets, there is much to be desired. A lot of broken stone is put on the streets and spread, but not rolled, and, of course, the result can be imagined. Mr. Reed.

Very good results are obtained in New Jersey by using a gravel as a binder for roads; and in Mercer County, for binding macadam, the County Supervisor of Roads uses screenings with some of the quarry strippings in them, and obtains very good results. With clean stone or clean screenings there is not so much binding quality.

R. A. MEEKER,† M. AM. SOC. C. E.—The speaker would like to suggest a slight amendment of the following clause in the Report: Mr. Meeker.

"Such proportions of the various sizes of material used as will result in the greatest possible density of the roadway, when properly compacted and bound, are desirable."

It is suggested that this be amended to read as follows:

"Such proportions of the various sizes of material used, separately applied, as will result in the greatest possible density of the roadway, when properly compacted and bound, are desirable."

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* Trenton, N. J.

† Plainfield, N. J.

Mr. Meeker. If an aggregate of large material is applied in one portion of the road and one of fine material in another portion, although the percentage of voids may be reduced by the addition of other fine material, there will be unequal wear in the road. The larger material will not wear as rapidly as the finer, and the road will be bumpy, wavy, and uneven. The material should be applied in courses; that is, if the gravel contains large particles, or is of a diameter greater than 2 in., it should be screened and applied in two courses.

There are certainly a great many gravel roads on which the material has been applied unscreened and in one course, but the matter can be shown very clearly: For example, if old Belgian blocks, 6-in. cubes, are put down, they will stand wear almost indefinitely; and if a road is built of nothing but ¾-in. stone, and is subjected to the same traffic, it will soon be utterly worn out and useless. That represents the two extremes.

Now, simply carry that idea into a crushed-stone road: If part of a road is covered with 2½-in. stone, and an adjoining section is built of ¾-in. stone, it is plain that the former will not wear out as rapidly as the latter. The result will be that where there is an aggregation of 2½-in. stone, there will be a hump in the road, and where there is one of ¾-in. stone, there will be a depression. All road builders who have noticed their work, and the effects of traffic on it, will agree on this point.

Mr. Johnson. A. N. JOHNSON,* M. AM. SOC. C. E.—The point brought out by Mr. Meeker has been very well stated. If, in the surface of a macadam road, there are masses of stone, some of larger and others of smaller size, that road will wear unevenly.

Considerable difficulty is caused by the non-uniformity in shipments of stone. On one day there will be more small sizes than one wishes to use, and on the next day all the stone will be of the larger sizes.

The speaker has adopted the practice of using unscreened material —unscreened so far as concerns the 1, 1½, or 2-in. sizes. They are spread on the road as they come, and then a very stiff-toothed harrow is passed over the road. The effect of that is to stir up the materials; and, if a collection of particles of various sizes is stirred up, the smaller ones invariably go to the bottom, and the larger ones come to the surface.

Although a road may be composed of pieces of stone varying in size from 2½ to 1 in., after it is harrowed about four times, the surface will be covered uniformly with the material of the largest size, which is the object to be attained, as it gives a homogeneous surface for the traffic to wear.

* Chicago, Ill.

The harrow also tends to compact the material. After harrowing, it will be found that the roller compacts the material with not more than half as much rolling as is usually required. Harrowing will often obviate the very troublesome, wavy effect when rolling. This is caused by the tendency of the larger particles to come to the top and the smaller particles to go to the bottom; but, after the harrowing has been done, each piece is where it belongs, and each course of stone is much more quickly compacted than by any other method. It is also much cheaper than to attempt to grade the stone and ship it in two sizes. Mr. Johnson.

CEMENT CONCRETE PAVEMENTS.

P. E. Green,* M. Am. Soc. C. E. (by letter).†—It seems to the writer that gravel as a road-building material has not been appreciated properly by the Engineering Profession. It is but rarely in technical literature that it is commended; yet in the gravel-producing parts of the country there are thousands of miles of gravel roads made by township and highway officials, crudely built, improperly maintained, and inadequately drained, and these roads are standing up remarkably under the large amount of automobile traffic that is characteristic of the present-day highways of any section where the roads are at all "good". Mr. Green.

A recent article‡ on gravel roads in New Hampshire and their maintenance seems to the writer to be one of the most sensible and well-balanced which he has ever read on the subject, and he would suggest, before the Committee makes its final report, that it thoroughly digest this article and seek further information on the subject. In reference to this matter, Table 1, an estimate the writer has made on what he considers a heavy traffic country highway, may be interesting. This is the highway from Chicago to Lake Geneva, Wisconsin, a popular summer resort.

In Table 1 it was assumed that a concrete road would last for 30 years (a most favorable assumption), and that the repairs would be based on a parabolic curve. It is understood, of course, that this curve is an assumption, but it is the writer's experience that, in the case of rigid wearing surfaces, it is the nearest approach to the economic line of repairs which can be assumed. For the gravel pavement the repairs are based on a straight-line increase year by year, for the reason that gravel roads are repaired entirely by the addition of new material, and that, if constantly repaired and kept in good condition, there should be no material increase year by year, but rather a gradual

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* Chicago, Ill.

† Received by the Secretary, January 3d, 1916.

‡ *Engineering News*, December 9th, 1915.

Mr. Green. thinning out of the total pavement, which at the end of its life will mean that an entirely new roadway will be constructed.

TABLE 1.—Comparative Costs of Cement Concrete and Gravel Roads.

Traffic: 600 vehicles per day for 7 months, mostly automobiles; and 100 vehicles per day for 5 months.

Kind of road.	Cost per mile.	Interest at 5 per cent.	Repairs.	Replacement fund, 4% compounded	Total yearly expense.
Cement concrete....	$12 000	$600	*$200	$214	$1 014
Gravel...............	4 000	200	†500	434	1 134

* Based on parabolic curve of repairs, 30 years life.
† Based on straight-line curve of repairs, 8 years life.

From Table 1 it appears that. under the most favorable conditions for concrete—in that its life is assumed to be 30 years—and with the traffic as assumed (and this is not entirely an assumption, but is an estimate of traffic on the road mentioned, based on the statement of a local official at McHenry, Ill., that counts had shown the Sunday traffic to be as high as 1 400 automobiles), the concrete road is only slightly cheaper than the gravel road, and hence it follows that for any considerable amount of traffic less than that assumed, the latter is the cheaper.

A further computation along the same lines, on the basis of oiling a gravel road twice a year, will show that the oiling is little, if any, cheaper than the necessary surfacing with fresh gravel. Oiling is not an unmixed blessing, as it is hardly possible to give such a surface continuous treatment. Hence, at times, between treatments, the road gets in very bad condition, because the pot-holes on an oiled or bituminous road are much more objectionable to the traveler than the ruts or hollows in an uncarpeted gravel road. The application of oil to a road means that no moisture can reach the interior, and it is believed that a small quantity of water is good for stone roads.

The Committee further states, under the heading "Cement-Concrete Pavements":

"Expansion joints, when provided in a roadway slab or pavement, should be designed and installed so as to interrupt to the minimum degree practicable the uniformity of the surface; should be placed at intervals of approximately 30 ft.; and may be built with advantage at an angle of from 70 to 80° with the axis of the road."

Is it the intention of the Committee completely to endorse expansion joints under this paragraph? A great many engineers engaged in the construction of pavements of this character are coming to

the conclusion that the use of expansion joints across a cement concrete wearing surface is a mistake, and that it is a greater mistake to build such expansion joints at an angle with the axis of the road. It has become generally acknowledged that cracks in concrete roads are unavoidable. These cracks, however, are seldom, if ever, caused by expansion, but are contraction cracks, and the expansion joints are absolutely useless to prevent them. Furthermore, expansion joints have a tendency to ride, especially if the joint departs slightly from the vertical, and this tendency seems to be greater when the joints are at an angle with the axis of the road than when they are perpendicular. A shining example of this is a well-known road in Lasalle County, Illinois, crossing the Illinois River bottom, where the expansion at the joints (which are at an angle of about 70° with the axis of the road) has caused heaving or riding, and is a very great annoyance to drivers of vehicles. It has been recognized for several years that with roads having a brick surface filled with cement, cross expansion joints are a detriment rather than a benefit, the reason being that such a joint is a source of weakness. The reasoning applies equally to cement concrete surfaces. Mr. Green.

Clark R. Mandigo,* Assoc. M. Am. Soc. C. E. (by letter).†— Although the Committee has "refrained from including in this report such conclusions regarding any material or method as appear to have been generally agreed on", many controversial points have been touched on so lightly or in such an unsatisfactory manner that the recommendations will not carry the weight which should be expected of the report. Mr. Mandigo.

For supporting a thin rigid monolithic slab pavement like cement-concrete, the preparation of the sub-grade becomes of much more importance than for other classes of pavement. The sub-grade is responsible for the majority of the cracks which appear in cement-concrete pavements, and emphasis should be laid on thorough drainage. The sand layer below can be made to improve the drainage of the sub-grade, and is of some value for that reason alone. The Committee leaves the question of expansion joints ambiguous by stating carefully where and how to place them "when provided in a roadway slab or pavement", but not stating its opinion as to their necessity. The fact of the matter is that transverse expansion joints in cement-concrete pavements are as much a detriment as were the transverse joints in the old cement-grouted brick pavements. It is the general practice of most engineers at present to omit them in favor of some form of cleavage plane or contraction joint. Kansas City has laid more than 50 miles of plain one-course concrete pavement during the past 3 years

* Kansas City, Mo.

† Received by the Secretary, January 14th, 1916.

Mr. Mandigo. without expansion joints, and with much better results than where such joints were formerly provided. Only two examples of disrupted transverse joints, due to expansion, have occurred, and these only on account of very careless construction. There is no progressive creeping of any of the long stretches of pavement. The present specifications particularly provide against joints of any kind, care being taken to make any line of weakness in the concrete, due to interruptions in laying, perpendicular to the surface of the pavement. It is the writer's opinion that no form of contraction or expansion joint should be used, so that the monolithic qualities of the pavement may be developed to the full extent.

The testing of materials is important, but of equal importance is the testing of the finished concrete, which is not mentioned by the Committee. Compressive tests of cylinders of concrete samples, taken in the field during the process of construction, give very desirable information. These tests, by comparison, soon show the best way to handle the various classes of materials in order to get the greatest uniformity and density.

Although mention is made of protecting and wetting the surface, nothing is said about preparing the sub-grade to prevent the too rapid drying out of the bottom of the concrete. Under certain conditions of weather and soil, this becomes as serious as surface drying.

Mr. Talbot. K. H. Talbot,* Jun. Am. Soc. C. E.—It is to be regretted that the Committee has not made more definite recommendations concerning the methods of construction and the selection of material for cement-concrete roads. The speaker realizes that there are so many points which should be given consideration that undoubtedly the Committee did not feel in a position to cover all of them thoroughly. At the same time, it would be well for this Committee to plan to present to the Society in detail those points which go to make up the best practice in concrete road construction.

To digress for a moment from cement-concrete pavements: Reference is made by the Committee to the selection of the kind of crust or pavement.† It would seem that, as the word "crust" is not in general use among road builders, it could be dispensed with, and that the word "pavement", carrying with it an idea of solidity and stability, together with an ability to withstand the traffic to which it is subjected, be considered to refer to all road surfaces covered in this report.

Turning now to the discussion of cement-concrete pavement: Reference is made to the necessity of a carefully prepared sub-grade, but nothing is said concerning the necessity for a uniformly compacted sub-grade. Uniformity is a matter of the utmost importance, particularly where the pavement is to be laid on old macadam or

* Pittsburgh, Pa.

† *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2723.

on any other hardened central core, even though this core be only the old compacted earth road. In either case, it is necessary that the surface be thoroughly rooted up and rolled to uniform density, in order that subsequent re-adjustment of the sub-grade may not result in uneven settlement. Uniformity of sub-grade is a necessity for success in a pavement of any type. Uniformity means, not only uniformity of compression, but also smoothness of the surface. Very often the contractor's foremen feel that they should be allowed to fill holes in the sub-grade with concrete rather than be required to fill them with earth. Such a practice is pernicious, and must result in unsatisfactory pavements. Mr. Talbot.

The Committee refers to the use of a layer of sand between the sub-grade and the concrete pavement. This practice is not general, and where used has shown no marked benefit. It adds another construction detail, however, which means additional expense, and unless it is very carefully underdrained, must act as a reservoir to draw all the surface water under the pavement instead of allowing it to take its natural course to the side-drain. It is impossible, of course, to compact such a sand bed uniformly. Re-adjustment subsequent to the placing of the concrete will set up secondary stresses in the concrete that may result in fracture. The movement of the water through the sand will undoubtedly aggravate this condition. It seems advisable, therefore, to place the concrete directly on a solid, carefully prepared sub-grade of the natural soil.

The speaker agrees with the Committee that joints should be placed approximately 30 ft. apart, but cannot agree with it as to the advisability of placing these joints at an angle of 70 or 80° with the center line of the pavement. The distance between joints will depend on a number of conditions, including the character of the sub-grade, the drainage, and the quantity of reinforcement used. In a reinforced pavement the distance between joints can be increased beyond that given in the report.

Although reference is made to the necessity of testing materials for concrete road construction, nothing is said as to the quality desired for such material. On page 3017* of the Report of 1914 sand is defined as "finely divided rock detritus the particles of which will pass a 10-mesh and be retained on a 200-mesh screen". Such material is not the most satisfactory for concrete construction, as experience goes to show that the highest strengths are available from fine aggregate containing material up to that passing a ¼-in. screen. The definition for fine aggregates given by the Specifications of the American Concrete Institute, for One-Course Concrete Highways, is:

"Fine aggregate shall consist of natural sand or screenings from hard, tough, durable crushed rock or gravel, consisting of quartzite

* *Proceedings*, Am. Soc. C. E., for December, 1914.

Mr. Talbot. grains or other equally hard material graded from fine to coarse with the coarse particles predominating. Fine aggregate, when dry, shall pass a screen having four (4) meshes per linear inch; not more than twenty-five (25) per cent. shall pass a sieve having fifty (50) meshes per linear inch, and not more than five (5) per cent. shall pass a sieve having one hundred (100) meshes per linear inch. Fine aggregate shall not contain vegetable or other deleterious matter, nor more than three (3) per cent. by weight of clay or loam. Routine field tests shall be made on fine aggregate as delivered. If there is more than five (5) per cent. of clay or loam by volume in one (1) hour's settlement after shaking in an excess of water, the material represented by the sample shall be held pending laboratory tests. Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement, and three (3) parts fine aggregate, by weight, when made into briquettes, shall show a tensile strength of briquettes composed of one (1) part of the same cement and three (3) parts Standard Ottawa sand by weight. The percentage of water used in making the briquettes of cement and fine aggregate shall be such as to produce a mortar of the same consistency as that of the Ottawa sand briquettes of standard consistency. In other respects all briquettes shall be made in accordance with the Report of Committee on Uniform Tests of Cement of the American Society of Civil Engineers."

It would seem that the Committee's definition for fine aggregate should be more definite.

Reference has been made by the Committee on page 2725* to the rational determination of the proportions of fine and coarse ingredients. Experience shows that the best results are obtained by the use of not less than one-half as much fine aggregate as coarse aggregate, provided the ¼-in. screen is considered the line of demarcation; in other words, that the fine aggregate meets the suggested specification just given. With certain classes of material, such as trap rock, limestone, and slag, it becomes necessary to increase the quantity of mortar, so that it will more than fill the voids in the stone, and thereby make the striking off of the concrete practicable.

The cement-concrete road is in fact a stone road bound by a cement and sand mortar, and the only way to insure satisfactory wearing quality for such construction is to make that mortar of sufficient strength to resist the impact and abrasion of traffic to which it is subjected. It is of the utmost importance, therefore, that the mortar used shall be of high tensile strength. Experience shows that such a mortar should be mixed in a proportion of 1 part of cement to 1½ parts of fine aggregate, or 1 part of cement to 2 parts of fine aggregate, depending on the material used in construction.

The consistency of the concrete at the time it is placed is of great importance. Tests have shown that the tendency on many jobs is to use too much water, and that with longer mixing this quantity of

* *Proceedings*, Am. Soc. C. E., for December, 1915.

water can be materially reduced and the strength of the concrete materially increased. It would seem that this is a matter to which the Committee should give careful consideration. Mr. Talbot.

The word "setting" is used in this report in reference to the hardening of concrete, and it is therefore not out of place to suggest that the word "set" is a laboratory term, and has no connection with the action of concrete. "Hardening" is a much better term, is as specific as "set", and has the further advantage of not being misunderstood. The last paragraph of this section of the report reads as follows: "In all cases the surface of the finished pavement should be kept wet and, if possible, protected from the sun for several days." The words "if possible" materially weaken the recommendation, and are not in line with the best practice. If these words were omitted, the recommendation would carry much more weight. The Committee apparently realizes the advisability of keeping the pavement wet and protected, but is willing to lose this advantage if it is difficult to obtain the proper material for covering and curing. Certainly, all concrete roads—and concrete of any kind, for that matter—must be protected from too rapid drying out, and, until such time as due consideration is given to this point, the care given to other points will be partly counteracted.

To digress somewhat from the matter covered by the report: Attention is called to the fact that the riding of one slab over another can be overcome without difficulty if proper attention is given to the construction of the joints at the time of placing the concrete. Examination of slabs which have raised has shown the joint to be at an angle to the surface of the road, due to carelessness at the time of construction.

Reinforcing steel should be as near the top of the slab as possible, without endangering traffic by placing it so close to the surface that it will eventually appear. The best distance apparently is approximately 2 in. from the top. It is advisable to place the steel near the top of the concrete in order that if cracks occur, from readjustment of sub-grade, or from whatever cause, they will be held in place by the reinforcing steel and will not be allowed to open. Engineers are not interested particularly in what happens to the bottom of the concrete slab, but are materially interested in seeing that any cracks which appear in the concrete pavement do not open so that they will be subjected to wear. Reinforcement is proving its efficiency in serving such a purpose, and, though it does nothing else, it will serve as binding steel to hold the concrete together, and will be well worth what it costs. The speaker thinks it has already proved its efficiency.

R. A. Meeker,* M. Am. Soc. C. E.—The speaker is entirely in accord with Mr. Talbot in regard to the protection of concrete from Mr. Meeker.

* Plainfield, N. J.

Mr. Meeker. the sun, and would go a step farther by amending the clause on page 2725* to read: "In all cases the surface of the finished pavement must be kept wet, and protected from the sun for several days," striking out the word "should", and substituting therefor the word "must", and striking out the words "if possible".

The first paragraph under Cement-Concrete Pavements, on page 2724,* reads:

"The sub-grade for a cement-concrete pavement should always be as carefully prepared, rolled, and compacted as for any other roadway, and should be made to conform to the proper lines and grades."

The speaker suggests that this be changed to read:

"The sub-grade for a cement-concrete pavement should always be more carefully prepared, rolled, and compacted than for any other roadway."

This suggestion is made because the strengths of concrete in compression and in tension are very different. In a good laboratory test, concrete will possibly attain a strength of 600 lb. in tension and 3 000 lb. in compression. There is comparatively no elasticity in concrete, but there is a certain amount of elasticity or mobility in other pavements—water-bound macadam, or gravel, or any of the others—which permits them to adjust themselves to the changing conditions of the foundation.

One of the first experimental roads built by the American Cement Manufacturers Association was in New Jersey, and longitudinal cracks appeared in it. The speaker knew the road as it was built originally, and it was very easy for him to determine why those cracks occurred, as one side was laid on the old water-bound macadam, and the other on the soft earth. The latter was more yielding than the old road, and, consequently, the pavement cracked, and the concrete was condemned for the fault of the sub-grade. In a certain case, witnessed by the speaker, the sub-grade of the pavement had been built about 3 in. too high. The contractor simply ploughed it up, and then put a roller on and mashed it down. This produced a comparatively uniform base, and that pavement has not cracked at all. Hence, it is easy to see that the more uniform the support for the concrete, the better the result will be, because concrete has so little mobility.

Cement-concrete pavements have been advocated because they are cheap, and, naturally, it is thought that they should be laid as quickly and as cheaply as possible. A grouted brick pavement is not recommended or advised because it is cheap. It is acknowledged to be an expensive pavement, more in the nature of a luxury than the country highway; and the precautions taken in securing the proper foundation for the grouted brick pavement, and in preparing the base on which

* *Proceedings*, Am. Soc. C. E., for December, 1915.

to lay the concrete, are much greater than those for many of the foundations prepared for ordinary concrete roads. Mr. Meeker.

It is not in a spirit of criticism, but of helpfulness, that the speaker makes these statements. An endeavor should be made to obtain the best results from this material which is being used so extensively, and he simply adds this word of caution, that engineers should be just as careful in preparing a sub-grade for a Portland cement-concrete road as for a brick road.

WILLIAM M. KINNEY,* JUN. AM. SOC. C. E.—The importance of careful preparation of the sub-grade should not be minimized. It is not so important that the sub-grade be "firmly" compacted as that it be "uniformly" compacted. An old macadam road, if not properly scarified and re-rolled, may make a far less satisfactory sub-grade than a relatively small but uniform fill on swampy ground. There would seem to be no reason for any difference in the treatment of the sub-grade for either brick or concrete roads. Mr. Kinney.

The Committee has done well to emphasize the importance of the thorough mixing of the concrete. In order to give the cement a chance to perform its function, it is essential that it be well distributed throughout the mass, so that each particle of aggregate, no matter how small, is coated with cement. To accomplish this in the best of batch mixers requires a minute or more, and any extra time given to mixing will more than pay for itself in quality attained. This is true of concrete used for pavement foundation purposes, but is especially true of that used for wearing surfaces. The time consumed in the mixing process would seem to be of considerably more importance than the order in which the materials are placed in the drum. It would be logical to assume, however, that the coarse aggregate helps to accomplish thorough mixing of the cement and sand, and that all aggregates and cement should enter the drum at the same time.

Hand in hand with insufficient mixing goes the tendency to use too much water. An excess of water makes the mixture look better, but quality and not looks is what is wanted. Only enough water should be used to make possible striking the surface with considerable effort.

The time when the surface is floated is also of considerable importance, and is frequently overlooked, because of the habit of the finisher to try to keep up with the mixing crew. Excess of water should be allowed to evaporate and the concrete to stiffen appreciably before floating is done. When the float is moved over the surface, the result should be a somewhat rough finish, not a smooth, slick surface, such as results when the concrete is floated too soon after being placed.

* Chicago, Ill.

Mr. Kinney.

There has been considerable discussion relative to the proper name for the joint in a concrete pavement. Whether to call it a contraction joint or an expansion joint seems to be of little importance, as movement takes place in both directions. If joints are not used, the concrete must have good strength and great density, in order that it will have the ability to move long stretches over the uneven sub-grade. To assist in overcoming this condition, the use of reinforcement has been recommended, and, where used, has given considerable satisfaction. The disadvantage of building a pavement without joints is that the cracks are not under control. They take an irregular course across the street, and sometimes run parallel to the center line of the pavement. Frequently, the crack does not occur in a vertical plane, and a thin fin or edge is left at the top of the pavement which breaks very easily under traffic. It is known that cracks must occur at certain intervals, and it seems well to have them controlled in the form of joints.

The Committee has recommended that joints be placed at an angle with the center line of the road. If this angle is made too sharp, the corners of the acute angle at the edge of the pavement have a tendency to break off. This suggests the desirability of having the angle, if other than 90°, only slightly less than 90°, so that the danger from cracking at the edges will be eliminated. On a 16-ft. road sufficient angle can be obtained by making the longitudinal distance between the two ends of the joints about 3 ft.

There seems to be considerable room for doubt as to the desirability of eliminating entirely the use of protection plates at joints. A number of concrete road builders are still using joint protection plates, and they consider them to be an advantage to the road. These men are building roads which are giving good service, and it would seem that their study of this subject must have moved them to go to that additional expense. It is possible that engineers will come to feel that their use is dependent on the character of the aggregate used in the concrete. For instance, with granite or a trap-rock aggregate, protection plates might be found to be unnecessary, but, with gravel and soft stone, they would be found to be desirable and economical. This is one of the many points still to be studied.

With reference to the matter of abrasion, a number of experiments are being made under the direction of Professor D. A. Abrams, at the Lewis Institute, Chicago, on the Talbot-Jones rattler, adapted for abrasion tests of concrete. The results of the experiments to date will be presented before the American Society for Testing Materials in June, 1916, and should lead to a considerable enlightenment on this subject. In connection with these experiments, there are also being made mortar compression tests in 2 by 4-in. cylinders, and concrete compression tests in 6 by 12-in. cylinders.

H. S. MATTIMORE,* Assoc. M. Am. Soc. C. E.—The speaker does not wish to raise a discussion regarding the distance between expansion joints, as there is such a variety of opinion in different sections of the country. In fact, in some of the Western States, such joints are not used. This type of construction has not yet reached that stage where the Committee should recommend any distances. If the distances are increased, it may result in an increase in the number of transverse cracks, and that should be studied in order to ascertain how their cost of maintenance compares with ordinary joints. Mr. Mattimore.

J. C. BENTLEY,† Assoc. M. Am. Soc. C. E.—The speaker has noticed, in several instances where concrete has been laid on a sub-grade of sandy composition, that the cement has penetrated into the sub-grade; in other words, the water has carried the cement out of the concrete and has thus weakened it. Is there not some possibility of conserving this strength by water-proofing the sub-grade so that it will retain the water in the concrete? Mr. Bentley.

P. H. WILSON,‡ M. Am. Soc. C. E.—In curing cement-concrete roads, there is a method which has been used with much success, particularly in the West. Dikes, 5 or 6 in. high, are built on each side of the concrete slab, the space between is flooded with water, and the water is kept on the concrete for a period ranging from 7 to 14 days, depending on the temperature. Thus, the concrete sets under perfect curing conditions. Mr. Wilson.

The Committee's Report states that the concrete should be "protected from the sun for several days". This is indefinite, and does not cover the period of curing. The words "several days" should certainly be "fourteen days".

In the specifications on page 2734, the cements to be accepted are referred to as those meeting the specifications of the "Society's Special Committee on Concrete and Reinforced Concrete". That Committee did not prepare the specifications for the testing of cement. This was done by the Special Committee on Uniform Tests of Cement. The tests of the latter Committee are very much more extensive and are those under which practically all cement is accepted to-day.

GEORGE C. WARREN,§ Esq.—Does not the question of the expansion depend on the cement to a great extent? Some years ago, the speaker was interested in a cement manufactured at a new plant. This cement had been insufficiently cured, but otherwise was as perfect as any ever put in a sidewalk. The slabs were about 4 ft. square, and the usual expansion joints were provided. In about 2 months, each of those slabs was like an inverted plate, and in many cases the concrete Mr. Warren.

* Albany, N. Y.

† Hackensack, N. J.

‡ Philadelphia, Pa.

§ Boston, Mass.

Mr. Warren. had expanded so much that it had deflected the 12-in. granite curb at the end of the work until it stood at an angle of about 45°, instead of 90° as it should. In that case the concrete simply expanded; but a properly manufactured and cured cement would doubtless have given no trouble.

More than 10 000 tests for determining the voids in mineral aggregates have been made in the laboratory of Warren Brothers Company, or more than made by any other organization or laboratory in the world. No one realized the importance of the voids in the aggregate, and therefore it was not incumbent on any one to make such a systematic series of tests.

Mr. August E. Schutte, who collaborated with the speaker's brother, the late Frederick John Warren, before the latter applied for the patents under which the Bitulithic pavement is being laid, devised a method which is now well known as the "Schutte Truncated Cone Test for Voids". This method has been used, without change, by the speaker's company, since 1900, not only for the determination of voids in a certain known aggregate, but also for the production of dense aggregates.

The truncated cone shape of the receptacle was adopted after numerous experiments to get concordant results—results checking with one another.

It was found that, if a vessel having vertical sides is used, the aggregate, in compacting, will change constantly during the test, the particles, especially the large ones, changing in juxtaposition. On starting a test, the coarse particles will first go to the bottom and there adjust themselves; the fine particles then will slowly sift and work to the bottom, and then arch and slowly but surely force the coarser particles upward. This will continue until the entire lower layer of the receptacle is composed of fine material, the coarser particles being forced up and out. The truncated sides of the cone prevent this, as the coarse particles, when once lodged in the proper places, cannot be forced upward. This was the reason for adopting the truncated cone.

Void tests which check very closely with each other can be made in a box having vertical sides, but much care must be taken in order to have the results check. The box must have a cover or sliding lid, and this must be held securely in place so as to prevent any movement of the coarse particles; and the sides of the box must be prevented from bulging. It is difficult to construct, and difficult to handle, such a box, and tests made with it lack the convenience, the accuracy, and the speed which characterize those made by the use of the cone.

The angle which the sides make with the base does not matter, if the desired effect is produced, that is, if the particles are prevented

from moving upward. Cones at various angles have been tried and have given practically the same results. It is natural that a very large cone for testing small aggregate will not have such an effect; and, again, it is obvious that a very small cone for testing aggregate of large size will introduce an error due to the "unnatural" void caused between the stone and the sides, or especially the bottom, of the cone. It has been customary, therefore, for an aggregate containing particles of about 1½ in. in diameter, to use a cone having a capacity of from 3 000 to 5 000 c.c.; and, for smaller aggregate, for instance, ¾-in. stone, a cone having a capacity of 1 000 c.c. is convenient. For sand, small cones of about 100 c.c. (a 100-c.c. glass flask) have given excellent results. However, if ¾-in. stone is tested in a cone having a capacity of from 3 000 to 5 000 c.c., the results will be almost identical with those obtained with the smaller cone; and large particles when tested with the smaller cone will give a large percentage of voids. Mr. Warren.

The selection of the proper cone is a matter of convenience and for the purpose of reducing the work of testing and introducing as small an error as possible, exactly as a chemist will select a flask or beaker of appropriate size for the test he intends to make and the quantity of material he intends to use.

The actual shape of the cone is also a matter of convenience. Large ones require bales or handles; smaller ones need only a neck at the top to facilitate grasping. The cones used by Mr. Schutte have a ring about 1 or 1½ in. high and about 2 in. in diameter at the upper end.

The thickness of the metal of which the cone is made is determined by the size of the aggregate, and the only criterion of the proper thickness is the utility of the instrument. If the metal is too thin it will stretch, and vitiate the result; and a cone made of very heavy metal is difficult to handle on account of its excess weight. The question is not how thick the metal should be, but only how thin it may be. For small cones, such as those of 1 000 c.c., $\frac{1}{16}$-in. metal is strong enough, and stretches very little (about 5 c.c. for ten tests); for larger cones, $\frac{3}{16}$-in. seems to be a very good thickness. Those figures refer only to the ordinary galvanized or boiler iron. If steel is used, the metal may be much lighter. The bottom of the cone is "dished", and riveted from the outside. This is most convenient and makes the strongest cone. The voids are tested in a compacted aggregate, that is, the aggregate is compacted until no more diminution in volume takes place. To stop at any other point before this takes place would be simply making an incomplete test, and would be no better than a guess. Care should be taken, in making a test, not to stop jarring, jostling, or pounding and tapping the cone until this point is reached. The matter of compacting has been carefully

Mr. Warren. studied, especially with the object of saving as much time as possible in making a test. The method which is most effective and also most economical in time is as follows: The cone is grasped at the top and shaken forcibly back and forth, while, at the same time, it is turned so that different parts of the bottom strike the block of wood on which the test is made, and then, occasionally, the cone is picked up and dropped flat on the base so that the whole bottom ring strikes at once. No set rule can be given for the number of gyrations or blows the cone should receive before the test is complete. Large cones require longer time and considerably more work than small ones, the object always being to get maximum and total compaction. An operator soon finds the method easiest for him that gives the quickest results. Shaking the cone forcibly for about a minute so that all the edges strike and then raising it 8 or 10 in. and letting it drop on the wood block, and repeating, seems to give the result in less time than any other method tried. The speaker uses a block of wood placed on a concrete foundation, and this is of such a height that the operator can sit on a stool when making a test. A block of wood forms a very convenient base for jarring the cone. It is not essential, however, for in some cases Mr. Schutte has used the granite window sill of a building after placing on it a piece of sole leather. Any convenient and firm base having on it some material such as leather or lead, so as to deaden the blow, may be used.

No special formula is required for calculating the voids; the aggregate, as compacted, is simply compared with the calculated solid weight. The difference, expressed as a percentage, represents the voids.

Determination of Voids in Mineral Aggregate by the Schutte Truncated Cone Method.—

1st.—Select a cone of such strength that it will not stretch or expand while the test is being made.

2d.—Select a cone of a size which will prevent the coarse particles from moving upward (1 000 c.c. for ¾-in. aggregate and smaller; 3 000 to 5 000 c.c. for 1½-in. aggregate).

3d.—Determine the capacity of the cone by filling it with distilled water and weighing it.

4th.—Determine the specific gravity of the aggregate. If the aggregate is of sand and stone, determine each separately and calculate the average specific gravity in accordance with the percentage found to obtain in the aggregate.

5th.—Determine the weight of the cone if filled solidly with the aggregate (multiplying the capacity, in grammes, by the specific gravity).

6th.—Mix the aggregate thoroughly. This is done preferably by placing it on a piece of paper, taking up one end and rolling the

whole mass until it assumes an elongated form, then taking up the opposite corner and rolling it up against itself. Place the aggregate in the cone, filling it nearly to the top. Place a piece of waste in the neck of the cone, and, while placing the fingers against the waste, commence jarring the cone. Add more material and continue until no more can be made to enter. Weigh the cone and the aggregate and determine the percentage of aggregate in the cone as compared with the solid weight. This gives the percentage of solid aggregate, and subtracting this from 100% gives the percentage of voids. The foregoing is expressed by the following equation: Mr. Warren.

$$\text{Percentage of voids} = \left\{ 1 - \frac{C - A}{(B - A)\, D} \right\} 100$$

in which A is the weight of the cone; B is the weight of the cone filled with water; C is the weight of the cone filled with compacted aggregate (all weights being in grammes); and D is the specific gravity of the aggregate. It is very convenient to have the weight of the cone an even number of grammes, such as 1 000 or 1 500 grammes, and the capacity of the cone also an even number, such as 1 000, 2 000, 4 000, etc. The weight of the cone can be easily increased by soldering lead around the upper ring; the capacity can be regulated by cutting off portions of the top.

A. N. Johnson,* M. Am. Soc. C. E.—On the speaker's first concrete road construction, he conceived the idea of placing the joints at an angle, because, at that time, it was thought necessary to use an armored joint, and, in placing such a joint, with steel edges, it is difficult to make it lie truly with the surface of the road, so that there is frequently a slight unevenness there. Mr. Johnson.

If that unevenness is great, vehicles will pass over the pavement better if the joint is at an angle, than if it is square across. On the other hand, where the practice is to leave out the armored joint, that condition disappears, because the joint can be made with true continuity of the surface of the pavement. Therefore, unless the armored joint is used, the speaker can see no reason for placing the joint otherwise than square across the road.

E. H. Thomes,† M. Am. Soc. C. E.—In the matter of expansion joints and reinforcements, it is well to consider the proportions and character of the materials; the conditions of temperature and moisture, both during and after construction; the difficulty in consolidating and finishing the concrete at expansion joints; and also the relative costs. Under what conditions is the additional cost justified? Mr. Thomes.

It is an open question whether or not transverse expansion joints and protection plates are beneficial. The speaker is of the opinion that

* Chicago, Ill.

† Jamaica, N. Y.

Mr. Thomes. they are not worth the expense of putting them in and the trouble caused by having them. It may be just as well to make a vertical, full-depth bituminous joint where the work is stopped noon and night, let the fine cracks form where they will, and then fill them with a small quantity of bitumen filler.

BRICK AND SLAG BLOCK PAVEMENTS.

Mr. Green. P. E. GREEN,* M. AM. SOC. C. E. (by letter).†—Under the heading "Brick and Slag Block Pavements", the Committee states:

"Toughness, resistance to wear from shock or abrasion, and non-absorption are essential qualities. The first two can be determined by the standard rattler test, and the last by the customary absorption test through immersion in water."

This paragraph, it would seem, must have been prepared several years ago, because, for several years, engineers engaged in work of this character have recognized that the absorption test for brick is absolutely useless, the reason being that an inferior brick having a skin which has been strongly vitrified, but a soft interior, will pass a very low absorption test, in fact, lower than an evenly burned block, though the latter will pass the abrasion test with honors and the other block will absolutely fail. Even the standard rattler test fails at times. The writer had a very clear illustration of this, in the summer of 1915, when he was requested to examine into the cause of the failure of a brick pavement in Chicago only 4 years old, and with a traffic of approximately 1 000 vehicles per day. The records showed that the bricks had passed the rattler test very well. The writer had a large number of the bricks taken from the street and tested in both the standard rattler and the old fashioned rattler, and in every case the bricks as taken from the street passed with an average loss of about 13%; nor did the individual bricks vary a great deal in their loss. Not until a very careful progressive rattler test was made by the Highway Department of the State of Illinois, the results being observed at the end of each 500 revolutions, was there any indication of the reason for the failure.

The Committee further states that the thickness of the sand cushion is often excessive, and that the function of this cushion is to give some resiliency to the wearing course. The writer agrees that the thickness is often excessive; but he doubts very much whether the function of the sand cushion is any other than to allow for irregularities in the surface of the foundation. He is of the opinion that a mortar cushion may be very desirable, especially on country highways, as shown by experiments of the State Highway Department

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* Chicago, Ill.

† Received by the Secretary, January 3d, 1916.

of Illinois and at Paris, Ill., where a mortar bed was used instead of the ordinary sand cushion. The main difficulty to be overcome, in the use of a cushion of this sort for city pavements, seems to be the lack of co-ordination between the arrival of the material and the contractor's labor. It is essential for an economical handling of the construction, from a contractor's viewpoint, that he be not compelled to lay off his labor, but that he can follow up the work in an orderly manner. It happens almost always that the brick is the last material to arrive. It is generally a fact that it has to be shipped farthest, and hence it seems that there is considerable irregularity in its delivery. The usual course in laying a brick pavement is for the grading gang to do its work and following it the concrete gang, and, when the concrete is laid far enough ahead and there is enough brick on hand, the concrete gang is very likely to be set to work laying brick. This is not possible with the use of an ordinary mortar cushion, which is intended to be made integral with the foundation. The bricklaying must proceed simultaneously with the concreting. Therefore, unless the materials are all promptly on hand, the contractor must lay off his men and stop the work, thus possibly losing his best and most experienced workers, who cannot afford to be idle for several days or weeks, as the case may be. This is an angle of the situation which must not be overlooked. Mr. Green.

Clark R. Mandigo,* Assoc. M. Am. Soc. C. E. (by letter).†—Under "Brick and Slag Block Pavements" non-absorption of the material is classed as an essential quality. The rattler test will reject brick as unsuitable for paving long before the absorption approaches that of building brick, or becomes high enough to be at all harmful. Porosity of brick is a factor of the clay or shale used and the method of burning, and, within considerable limits, does not indicate anything as to the durability of the brick. An investigation into the durability of the early, "soft", high absorptive brick pavements should be convincing on this point. It is, in fact, a question whether we have not gone to the other extreme in not putting minimum limits to the toughness of paving brick, so as to be certain to provide material which will abrade slightly under traffic. It is true that, with a given brand of paving brick, the compressive strength and the weight per cubic foot increase with a decrease in absorption, but so does the modulus of elasticity, and probably the coefficient of expansion, making the strains due to thermal action much more intense. A non-absorption test is also very difficult for many manufacturers to meet. The absorption of different bricks of the same exterior appearance varies, the products of various manufacturers vary, the quantity of absorption varies with the extent and kind of air drying the brick receives Mr. Mandigo.

* Kansas City, Mo.

† Received by the Secretary, January 14th, 1916.

Mr. Mandigo. before being brought to the laboratory, and, in making paving brick which will stand the rattler test and give good service in the street, the manufacturer cannot control the porosity absolutely.

Nothing is said by the Committee in regard to bituminous fillers, although in the West and Southwest, high-grade asphalt fillers have given good satisfaction for a number of years, and cement grout has not been at all successful. The asphalt fillers, however, should be used with the minimum width of joint possible.

Where a sand bed is used, it is very desirable to reduce it to a maximum depth of ¾ in. Specifications should insure an even concrete foundation laid to a template and a variation in depth of brick not to exceed ½ in., so that a thin sand bed will be practical. The sand bed has been responsible for many defective brick streets, and a reduction in the standard depth, to a point as low as is consistent with proper bedding of the bricks, is necessary on account of the difficulty of compacting the sand uniformly. It cannot be denied that a thin, thoroughly compacted, confined sand bed has no more resiliency than the concrete base on which it rests. The cement-sand bed performs all the essential functions of a sand bed and has the added advantages of remaining permanently in place, maintaining the bricks in their original position, and very materially reducing the noise. To be most successful, the water should be added to set the cement after the rolling and just before placing the joint filler. These remarks on sand beds apply with equal force to stone block pavements. The reduction in the noisiness of stone block pavements by the use of bituminous filler is not so much due to the filler as to the fact that the soft filler allows the blocks to adjust themselves from time to time to the vagaries of the plain sand bed, and be solidly bedded in compacted sand. Comparison of the noise produced by a vehicle going over a cement grouted, stone block pavement in a plain sand bed with that made by the same vehicle passing over a pavement with a cement mortar bed shows a very startling and a very real difference in favor of the mortar bed. Resilience—if there ever is any worth mentioning on a well-built pavement—is not a factor in noise elimination.

Nothing is said by the Committee regarding the reduction in depth of the wearing surface of either brick or stone block pavements. The standard depths have come down to us from early days, and, with modern methods of testing materials and construction, there is a question whether or not these depths are necessary, except on the heaviest traffic streets. Certainly, economy in design requires the engineer to take advantage of the least thickness of surfacing that will sustain the traffic of the road or street to be paved. A report from those who have tried a reduced thickness of wearing surface, together with a traffic census, would undoubtedly furnish much useful information.

PRÉVOST HUBBARD,* ASSOC. AM. SOC. C. E.—Attention is called to a slight oversight in connection with "absorption". The first sentence under "Brick and Slag Block Pavement", page 2725,† reads: "Toughness, resistance to wear from shock or abrasion, and non-absorption are essential qualities". This is all right, but, on pages 2731 and 2733,† under "Tests for Paving Brick", no "absorption test" appears. Mr. Hubbard.

In connection with the subject of a filler for brick pavements, the following statement occurs on page 2726,† under the heading "Stone Block Pavements":

"As it is desirable to secure a suitable water-proof wearing course for pavements, sand should never be used alone as the joint filler. A bituminous filler may be preferred to a cement grout filler on account of the lower cost of street-opening repairs, the better foothold provided for horses, and the securing of a more resilient and, hence, less noisy pavement."

Why should not this argument also be applied to fillers for brick pavements? In the second paragraph under the heading "Brick and Slag Block Pavements", no reference is made to this matter. Why were bituminous fillers not considered for brick pavements, when their advantages for stone block pavements are set forth so fully?

The speaker is very much interested in this question of the use of bituminous fillers for brick pavements. The Committee has referred to the use of sand joints, that is, sand fillers for joints, as occasionally justified in the interests of economy; and it says that cement joints, when properly made, will maintain the integrity of the surface, but special skill and care in application are essential. It has said nothing, however, as regards the bituminous filler. It is suggested that, in the discussion of fillers for brick and slag block pavements, bituminous fillers be recognized in the same general manner as for stone blocks.

T. J. McGOVERN,‡ ESQ.—The speaker does not know much about bituminous fillers for brick pavements, but laid some brick pavements with a cement filler, 22 years ago, and the joints are in very good condition to-day. The bituminous filler is less noisy than the cement, and a joint made of bituminous material and sand acts very well as an expansion joint; and it should be as effective in a filler for a brick pavement. Mr. McGovern.

There is nothing better for a filler than the ordinary sheet asphalt composition, either for vitrified brick, stone block, or slag block. There are quite a number of cases of brick pavements in which the joints are not filled with anything but hot asphalt, melted sufficiently to pour.

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* Washington, D. C.

† *Proceedings*, Am. Soc. C. E., for December, 1915.

‡ Trenton, N. J.

Mr. McGovern.

On hot or warm days, the asphalt runs from the joints, but the composition sand and asphalt joints stick well and protect the edges of the bricks.

The asphalt and sand were mixed in a brick form, about ½ in. thick. These bricks were not made in a press. The mixture was tamped into the side of an old I-beam. These bricks were placed where an expansion joint was required, and were laid only as expansion joints, and along the gutters. The remaining courses were filled with cement.

Mr. Thomes.

E. H. Thomes,* M. Am. Soc. C. E.—The speaker would call to the attention of the Committee the advisability of providing for more detailed information in the forms given in Appendix A of the report. In the matter of records, it is better to have too much information than not enough. Two pavements may be constructed with the same materials and methods and both may appear to be alike, but one may be a success and the other a failure. Unless full information concerning all details and conditions is available, engineers are unable to determine the causes of the good or poor results. Much careful investigation of the many various conditions is necessary, in order to determine the relative importance of each factor.

It has been stated that further information may be given under Remarks. Any information may be given under Remarks, but the reporter is requested to note any special traffic characteristics under that heading; however, unless some mention is made of other details, he is much less likely to record valuable information which otherwise would not be obtained. No harm is done by asking for more details, and much may be gained. Under Remarks may be stated any special methods or equipments used and any special conditions effecting good or poor results. When possible, state the minimum, maximum, and average results of tests, quantity represented, and number of tests. Some additional information along the following lines is suggested:

General Information.—Nature of sub-grade; drainage conditions; character and dimension of shoulder, gutter, curb, etc.; and conditions of maintenance, cleaning, sprinkling, etc., of both pavement and shoulder.

Foundation.—Materials and proportions.

Wearing Course.—Character, proportions, and size of joints; depth of bed; proportions; and analysis of all materials used.

Sand.—Natural, screened, washed; the mineral composition; character of the grains; percentage of clay; and percentage of organic matter.

The tensile strength of cement briquettes as compared with those in which standard Ottawa sand is used seems to be more indefinite and of less practical value than the tensile strength of the 1 : 3 mortar, in pounds per square inch, at 7 and 28 days.

* Jamaica, N. Y.

Mr. Thomes.

The results obtained with Ottawa sand are more for a test and comparison of the cement used, and it is well to record these results, and also the tests of the cement, but the information desired most is the strength of the sand and cement, and instead of specifying this by a percentage compared with Ottawa sand, why not specify and record the actual strength, in pounds per square inch, of the mortar or concrete. The relative percentage of strength of two sands varies somewhat, according to the character of the cement.

The compressive strength is a more important test than the tensile strength, but it is not so easily made. It would seem advisable to provide a blank for all tests of the cement, and fine and coarse aggregates, showing minimum, maximum, and average tests, age, size of test piece, etc.

The data on paving brick offered by Mr. Howard are the best known to the speaker.

Mr. Connell.

W. H. Connell,* Assoc. M. Am. Soc. C. E.—There has been a great deal of experimenting recently for the purpose of finding some bituminous filler which could be put into the joints between the bricks without smearing it all over the surface and changing the appearance of the brick pavement to that of an asphalt pavement.

It seems to be recognized more or less generally that the best bituminous filler is a mixture of about half sand and half tar, or sand and asphalt. Of course, the tar and asphalt should meet the requirements of a definite specification. The difficulty has been to find some method of placing the filler in the joint without smearing it and covering the whole surface.

The method used in a good many cases has been simply to pour the hot sand and asphalt on the brick, and then use a rubber squeegee and shove it into the joints. Of course, that discolors the pavement and changes its entire appearance. There is a lack of information as to a proper machine to use, or the proper means of putting this filler into the joints. The speaker is of the opinion that it would make a very desirable filler.

Has the Committee knowledge of any research work that will eventually enable engineers to specify the percentages of the different materials that go to make up the brick? Most of the discussions on brick relate to the finished product. It has been the speaker's experience with all other paving materials that, before one could get the best results in connection with these materials, it was necessary to control the plant inspection. As to bricks, engineers simply inspect and test the finished product, but it would seem that the inspection should cover the different materials that go to make up the brick, and its manufacture.

Mr. Crosby is right in his suggestion that there should be a different standard of requirements for bricks, depending on the traffic conditions.

* Philadelphia, Pa.

Mr. Connell. It is hoped that the Committee will conduct some research work in connection with the actual manufacture of paving brick, because, in order to get a satisfactory brick pavement without the present variation in individual bricks, it is necessary to have more scientific control, from the standpoint of the engineer, over the manufacture of the brick.

At present, engineers are carrying on plant inspection on bituminous and other materials for paving purposes, but are not conducting that kind of an inspection relative to brick. If more research work was done by engineers, in conjunction with the manufacturers, relative to the materials which make up the brick itself, there would be more advance in connection with the ultimate object that all have in view, that is, to procure a uniform brick. It is hoped that this phase of the subject will be taken up very seriously by the Committee.

Mr. Perkins. WILLIAM W. C. PERKINS,* M. AM. SOC. C. E.—When the final report of this Committee is published, it is possible that it may be made the framework for specifications, and, therefore, the speaker would suggest that the Committee consider in detail the methods of construction, as well as the materials, which will aid in making good brick or other types of pavements, or in obtaining a durable crust or wearing surface for them.

The speaker does not know exactly the scope of the Committee, but thinks it is only to report on the wearing surface of the pavements, although he firmly believes that a great deal depends on the proper preparation and drainage of the sub-grade, and also on the proper preparation of the foundation for the wearing surface. If the scope of the Committee includes these features, it would be well to consider them in the report.

The first clause under "Brick and Slag Block Pavements" (page 2723†), states that "toughness, resistance to wear from shock or abrasion, and non-absorption are essential qualities", for a paving brick. If the Committee wishes to consider absorption, the speaker would suggest that the term "very small absorption" be used, because it would not be practical, in fact it would be impossible, to make a brick non-absorbent.

Five or six years ago the manufacturers claimed that they could not make a standard-sized paving brick, although the American Society of Municipal Engineers endeavored at that time to establish a standard. Since then, it has been proved that such a paving brick can be made; and the speaker would suggest that the Committee recommend the manufacture of a paving brick of standard size, which is $8\frac{1}{2}$ in. long and $3\frac{1}{2}$ in. wide, with slight variations. In regard to the depth, the present standard is 4 in., but the reduction of this

* Conneaut, Ohio.

† *Proceedings*, Am. Soc. C. E., for December, 1915.

dimension, from 4 to 3½ in., or even to 3 in., for certain types of construction, is being asked for by many engineers. Mr. Perkins.

The standard size, 8½ in. long and 3½ in. wide, lays up 40 to the yard, and enables any municipality to repair a brick pavement with the bricks of any manufacturer.

The standard depth, 4 in., should not be reduced to less than 3 in.; but this change of depth is in an experimental stage. The speaker would not lay 3½ or 3-in. bricks on a plain sand cushion. He would lay them on cement-sand, or directly in the concrete.

The speaker is glad to note that the Committee has endorsed the cement filler. It is not claimed that it is absolutely perfect. There is room for improvement, but, at present, such a filler is the best that can be used, as it makes the pavement practically monolithic, water-proof, smooth, and sanitary, and protects the edges of the brick from abrasion by the traffic.

Mr. Connell mentions a filler which has been developed during the past year. The speaker has seen several streets on which it has been used, and thinks that good results may be obtained with it. The difficulty is in the application. In the first place, it has been difficult to heat the sand to the proper temperature, and get it mixed with the tar or asphalt. It is believed that machines are being made for the purpose of overcoming that trouble.

The Committee states that "uniformity in the cement grout and special skill and care in its application are essential to success". Special skill and care in application have been essential in the past, but a great many failures in cement-grouted brick pavements have been due, not particularly to the application, but to the choice of the materials used, that is, the sand, the cement, and the water. A graded sand should be specified for the grout. The quantity of water used in mixing the grout should be regulated, for, as a rule, too much is applied. The cement and sand should be thoroughly mixed dry, and the water should be added in small quantities, until the right consistency is obtained. The right consistency is a problem; the old specifications state that the grout should be of the consistency of thin cream; but, as one engineer has said:

"If it is true that the right consistency of grout is to be like thin cream, why not specify that our coarse aggregate in the concrete should be of the size of small green apples."

The speaker understands that an attempt is being made to determine the right consistency by finding the normal consistency of the cement and sand, but, in any case, the water should be regulated so that the grout will flow into the spaces between the bricks, and not be so thin that the cement will separate from the sand.

In regard to the application, if the sand and cement are thoroughly mixed dry, and then the water is added uniformly, the method of

Mr. Perkins. application is not so difficult as it has been made to appear in the past.

The speaker believes in using a small, properly equipped concrete mixer in putting on the first grout, as it produces a more intimate mixture of the cement and sand than can be obtained by mixing in a box.

In regard to the shape of the brick, the Committee suggests that "such form of the individual brick or block is desirable as will automatically provide sufficient, but not too wide, joints, and as will insure uniformity in their width, even when they are laid rapidly and with ordinary care".

The speaker agrees with the Committee thoroughly. There is no doubt that the bond in a cement-grouted brick pavement is of the utmost importance. The joints should be absolutely uniform. The lugs or projections also should be uniform, and it is hoped that the Committee will investigate and report against the use of a bar-lug, that is, a lug extending entirely across the brick, and also against the use of raised letters on the side of the brick. The bar-lug has a tendency to pocket the cement grout; and the raised letters will bridge the grout in the joint, thus, in each case, giving a weak bond. Absolute uniformity of the lugs or projections is essential to obtain a strong bond.

The speaker also thinks that the Committee should specify a brick with square edges, and not allow rounded edges. A square-edged brick can be made by all manufacturers, and there is no advantage in using one with rounded edges. The latter unquestionably reduces the bond from 4 to approximately 3½ in., and the cement grout will chip out under traffic and, eventually, the rounded edge will cobble, and the pavement become rough.

The question of the sand cushion has been thoroughly discussed in the technical papers. The speaker never could see the sense of using a yielding substance like sand between the brick wearing surface and the concrete. It cannot be controlled, and it varies in density and in thickness. Nor could he ever see the reason for specifying 2 in., and notes that the Committee has advised a reduction to 1 in. The contractors surely can bring the foundation to grade and contour so that it will not vary more than ½ in., and the bricks should not vary more than ⅛ in. in depth, so that there is plenty of leeway in using a 1-in. sand cushion.

However, it is hoped that the Committee, in its next report, will go further than this, and advise the entire elimination of the sand cushion and substitute for it a cement-sand bed of such proportions as it thinks advisable, whether 1:3, 1:4, or 1:5. This can be laid dry, like the old cushion; then the bricks should be laid on it, rolled, and well wet down before grouting. This will cause the cement

bed to set, and make, not theoretically, but practically, a monolithic structure; or possibly the Committee may go further, and advise laying the bricks directly on the green concrete, as is being done in Illinois and several other places. This is thoroughly practical, and would lessen the cost of pavements. Mr. Perkins.

In regard to cement-sand beds, the speaker would refer the Committee to places where they have been used during the past year: the City of Baltimore, where all brick pavements constructed during 1915 have been laid on a cement-sand bed, 1 in. thick, composed of 1: 5 cement and sand; Cuyahoga County, Ohio, in which Cleveland is situated, has laid more than 50 000 sq. yd. of this form of construction on its highways; the inclined approaches to the Pennsylvania Railroad Terminal in New York City were laid in 1910 with 2½ in. brick on a 1: 3 cement-sand bed, and the good results obtained can be seen by inspection.

It is noted that the Committee also mentions bituminous beds or cushions. The speaker is not familiar with this type, and would like to know the results obtained by the use of such materials. If a cement-sand cushion is used, or if the bricks are laid directly on the concrete, engineers can design a pavement more economically. If it is possible to obtain a monolithic slab by joining the brick wearing surface with the concrete foundation, why use a 4-in. brick for the wearing surface?

The great expense of brick is due to the freight. Standard bricks, 8½ by 3½ by 4 in. in depth, weigh 5 tons per 1 000, and the freight to New York is about $15 or $16 per 1 000; so that, if the depth of the brick can be reduced, it will reduce the freight charges. A brick pavement is never worn out by the actual wearing down of the surface; therefore, as stated before, engineers are considering a brick 3 in. in depth for monolithic or semi-monolithic construction.

In regard to the test specified on page 2743,* the speaker would suggest to the Committee to consider, as it probably has, the report of Committee C-3 of the American Society for Testing Materials, in regard to tests for brick. This report was adopted by that Society at the Atlantic City meeting in 1915, after extensive investigations by its Committee.

On page 2743*, it is stated:

"Each brick should be marked by small holes drilled in one of the faces of the brick, and the initial weight of each brick * * * should be determined."

The speaker would not advise the testing of the individual bricks. He cannot see any material advantage which would compensate for the trouble and expense of making this test. Samples are selected uniformly, and, under ordinary circumstances, there would be no wide

* *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Perkins. variation in the test, unless a brick breaks or a corner is knocked off during the test. The engineer should make tests of the different varieties of brick. The samples for testing should include ten of the light, ten of the dark, and ten of the medium colored bricks.

The speaker has been asked: Why does the Western Brick Association recommend the use of bituminous fillers? He does not know its reasons, but possibly they may include the following:

West of the Mississippi the majority of the bricks laid are what are called vertical fire bricks, in which the lugs or projections are made as they come out of the die. These lugs are about 1 in. wide, extending across the brick, three to each brick, so that 3 in. of the 8 in. of the brick are taken up with lugs. When these bricks are laid side by side, the wide lugs prevent the proper penetration of a cement binding grout, and the result is a very poor bond. A bituminous filler does not make a monolithic pavement and, therefore, there is no attempt to bond the brick thoroughly.

A report on the chemical composition of brick, by Professor R. T. Stull, of the Ceramic Department of the University of Illinois, will be forwarded to the Committee by the speaker.

Ceramic engineers and manufacturers state that it is not possible to know what kind of brick can be obtained from shale, unless it has been tested by burning. The shale may be examined, both chemically and physically, and the statement may be made that it will or will not make a good brick, but the only way this can be determined absolutely is to burn it and then test it.

The speaker can express no opinion regarding the relative value of the rattler test as compared with tests of bricks by their color. The rattler test, like the cement-grout filler, has its failings, but it is the best we have at the present time. Mr. Schuyler, in charge of tests for the City of St. Louis, is working out a test by using the sand blast, to which the Committee might give some attention.

Brick manufacturers welcome plant inspection. Variations in brick, as to color and quality, are not always caused by the material, but by the burning, and, during the last 4 or 5 years, manufacturers have been devoting more attention to this feature, so that the product is now more uniform.

Mr. Myers. J. E. Myers,* Esq.—The speaker would suggest to the Committee that provision be made in the brick tests for drying the bricks before they are placed in the rattler. Bricks which have been dried retain large dust accumulations, and this affects the test. It is found that the absorption test usually checks the rattler test. Mr. Perkins has suggested running tests on the light, dark, and medium burned bricks.

Mr. Green, in his reference to absorption, evidently overlooked the

* Albany, N. Y.

fact that the absorption test is usually made on bricks after they are abraded. Mr. Myers.

H. B. Drowne,* Assoc. M. Am. Soc. C. E.—The majority of specifications for vitrified paving brick stipulate that the quality of the brick shall be determined by the rattler test, the average loss of the bricks in the charge being taken as the criterion of the test. If the individual loss on each brick is recorded, it will be found that the loss on some of the bricks in the charge may vary widely from the average. The speaker has tested brick which would pass specifications based on the average loss, but would have to be rejected if based on the individual loss. There are relatively few specifications which require the acceptance of the brick to be based on the individual rather than on the average loss. Before a specification incorporating the individual loss feature is generally adopted, the speaker believes that the brick manufacturers should be consulted in order to ascertain whether it would be practicable for them to supply the present demand for brick under both types of specifications without unduly raising the price. Mr. Drowne.

W. W. Crosby,† M. Am. Soc. C. E.—In reply to Mr. Drowne, the speaker may state that, in Maryland, considerable experience has been acquired in making the individual record in the test for paving brick. The specifications there were drawn regarding an average loss, and. for any brick, not permitting more than a certain variation from the average. A number of lots of brick were rejected, and, as a large quantity of brickwork was contemplated, some of the manufacturers thought it worth while to take up the question with the speaker. The manufacturers wished to have the clause waived, and brick admitted on the average result of the tests, regardless of the variation of individual bricks. They were informed that that was then impossible, as the specifications had been established. Finally, they agreed that, in taking the bricks out of the kiln, it was entirely possible to select them in such a way that the variation in the individual bricks would be reduced to a minimum, and that, by another way of selecting them, the variation would be a maximum. They agreed that for the Maryland work they would make their selection in a way which would produce the result specified in the contract. Mr. Crosby.

Thereafter, there were remarkably few—in fact, scarcely any—rejections of lots of brick because of the individual variation from the average required. That, to the speaker's mind, proved the possibilities of the situation; and he firmly believes that the uniformity of the pavements secured was higher than would otherwise have been the case. The pavements are now from 4 to 8 years old. Experience with them has proved the assumptions.

* New York City.

† Baltimore, Md.

Mr. Crosby. Naturally, if a high average standard were to be required, and, at the same time, a low variation in individual bricks permitted, an increase in price might result; but, under different conditions, variations might be permitted in the standard; that is, an average loss higher than would otherwise be permissible could be admitted, provided the variation were within limits, under light traffic. Uniform wear, even though rapid, is not as undesirable as ununiform wear, though less rapid. The deterioration of brick pavements usually seems to begin in spots, from the failure of individual bricks, and those spots, having deteriorated to a certain extent, rapidly enlarge, and the surface of the pavement becomes objectionably uneven.

If the pavement should wear down evenly, even though more rapidly, the unsatisfactory condition of the surface would not be apparent nearly as soon. If this variation of the standard is adopted, the high standard being required for the severe traffic and a lower standard being allowed for less severe traffic, it would seem to the speaker that the problem of price would take care of itself. The manufacturer, having selected his brick so as to produce different grades of reasonable uniformity, would be able to dispose of his product without necessarily making any increase in price, especially as manufacturers state that such a selection is entirely practicable, although it had not been customary up to that time.

STONE BLOCK PAVEMENTS.

Mr. Green. P. E. Green,* M. Am. Soc. C. E. (by letter).†—It is believed by the writer that the Committee makes a further mistake when it says, under the heading "Stone Block Pavements":

"A bituminous filler may be preferred to a cement grout filler on account of the lower cost of street-opening repairs, the better foothold provided for horses, and the securing of a more resilient and, hence, less noisy pavement."

The last two reasons in this sentence are faulty, that is, the better foothold provided for horses and the securing of a more resilient and, hence, less noisy pavement. On all ordinary streets and grades, the better foothold provided for horses, if a bituminous filler is used, is more than offset by the very much larger traffic effort required to move the load, and it is only on very steep grades that such a reason could hold. On these very steep grades, by the use of a special construction, a cement grout filler may easily be secured, with its accompanying advantages. Furthermore, a properly applied cement grout filler makes a pavement much less noisy than a bituminous filler. A noisy pavement is but little the result of the character of the filler itself, but is

* Chicago, Ill.

† Received by the Secretary, January 3d, 1916.

due to the fact that if the edges of the brick or block are broken down, a series of wide, rough joints are thus formed, and it is the bumping and battering over these joints that causes the noise. Such a condition is inevitable with a bituminous filled brick or stone block pavement, and is just as absolutely eradicated by the use of a cement grout filler properly applied. With age, a cement grout filled pavement becomes smoother and quieter, and the contrary is true of a bituminous pavement. Most of the troubles of cement filled pavements have been caused by improper construction. Mr. Green.

It is believed that there are not many engineers, who have thoroughly investigated the question and have utilized both bituminous fillers and cement grout fillers for brick and stone block pavements, who would not prefer the cement grouted product.

PHILIP P. SHARPLES,* ESQ. (by letter).†—Mastic filler was introduced into New York after a number of the New York officials had returned from the London International Congress of Roads. The idea was obtained from the work done by Mr. John Brodie, in Liverpool. Some of the comments made by Mr. Thomes in regard to the use of the mastic in New York would seem to show that difficulties had arisen that had seemingly already been overcome by Mr. Brodie. The difficulty that Mr. Thomes has stated as existing in the New York work, of the sand settling in the pitch, is due to two reasons: The sand used in New York is too coarse, and the methods of mixing are rather crude. Mr. Sharples.

Mr. Thomes points out that the pouring pots have not been of the proper kind, and much better results can be obtained if their nozzles reach to the bottom of the cans so that no pocket is formed to catch the sand.

Experiments in Cleveland have shown that it is possible to use a much finer sand with very much better results, and to use some form of apparatus to mix the sand and the pitch together. It has also been found that certain precautions in regard to temperatures are necessary in order to have the work go on easily. The sand should be heated to at least 300° Fahr., and should be of a slightly higher temperature than the pitch. This makes the sand mix more easily and also seems to keep it from settling too quickly.

When mixing machines (3 to 4-ft. batch mixers) have been used, a modification of the methods of using the mastic has been found desirable. Instead of pouring cans, small, steel buckets mounted on wheels have been used to transfer the mastic from the mixer to the point where it is to be used. The whole load is then dumped at once on the paving and distributed with squeegees. Before the mastic has cooled, another load is dumped approximately where the first one was

* Gen. Mgr., Tarvia Dept., Barrett Mfg. Co., New York City.

† Received by the Secretary, April 10th, 1916.

Mr. Sharples placed. This is again pushed forward with squeegees, and the next load is dumped over the part last squeegeed. In this way it is possible to fill every joint thoroughly, even in cold November weather. Portions of a pavement in Cleveland laid in November were dug up within a week, and every joint was found perfectly filled. In the Cleveland work, an asphalt sand was used. It was brought directly from the heater in an asphalt plant, so that there was no difficulty in regard to heating it. It would seem that the same method might be adopted in the New York work to advantage.

In city work the advantages of the mastic filler over a grout filler are obvious. The bituminous filler produces a much less noisy pavement,—one that can be opened to traffic as soon as finished—and one that can be opened for the repair of service mains without any great difficulty. The blocks taken out in making the openings can be replaced again, as they may be removed without breaking them. This is a very distinct advantage in city work, as figures obtained show that the cost of making openings in a grouted pavement is excessively high, and also the cost of replacing, as it is necessary to use a large number of new blocks. Some of the criticisms of a bituminous filler do not apply to the new, closely dressed blocks now in use in New York. Pavements with these new blocks and bituminous filler, which have been in for 2 years, show no tendency to turtleback, because the edges protect each other owing to the closeness of the blocks.

Mastic filler has also been tried in brickwork, and has been found to give exceedingly good results. Enough time has not yet elapsed to show definitely the wearing qualities of a brick street built with mastic grout in comparison with cement grout, but it is certainly true that the brick are well protected on the edges, and, at the same time, a foothold for horses is secured, which is of the utmost importance on grades. A section treated on the Worcester Pike, outside of Cleveland, has gone through two winters and has given excellent satisfaction. Certainly, a grouted brick on the same grade would have been exceedingly slippery. The same is true in regard to grouted stone block on a grade. The instance cited of State Street, Albany, as a good grouted block street, would seem to show the necessity of a bituminous grout there. The grade is considerable, and horses find it very difficult, even in dry weather; with a bituminous mastic filler, they would have no difficulty.

Mr. Talbot. K. H. TALBOT,* JUN. AM. SOC. C. E.—The speaker agrees with Mr. Green as to the wearing qualities of stone block with cement grout filler. The worst feature of blocks, either of trap rock or sandstone, with soft or sand filler, is the tendency to cobble under traffic, thus becoming noisy, and slippery in wet weather, so that any advantages which may be claimed for the joint between the blocks as a foothold for horses is nullified. The City of Pittsburgh has used the

* Pittsburgh, Pa.

bituminous filler with a heavy gravel bed on top of a concrete foundation. The result is that the cobbling of the blocks results in noisy streets which are difficult to maintain and to clean, and, as they are always cut up more or less by street-car, water, sewer, and other repairs, they are not restored in good order. Certainly, the use of a cement sand cushion or a cement mortar bed in which the blocks are laid, would prove a great advance in the construction of stone block pavement. Probably one of the most interesting pieces of work which has come to the speaker's knowledge is the State Street hill in Albany, N. Y., which was paved in 1914 with stone blocks. This job was evidently very carefully grouted, as the grout remained on the surface, without wearing down to the blocks, in many places for a year and a half. This street, being on a 12% grade, is subjected to extremely heavy traffic and the grinding of steel tires going down hill under the control of brakes. Of course, greater care will be necessary in the selection of blocks if a comparatively thin mortar bed is used and the joints are built with cement grout. However, the speaker is convinced that additional care and expense are entirely justified by the results obtained, and would suggest that the Committee make reference to the allowable variation in the size of blocks. Mr. Talbot.

H. S. MATTIMORE,* ASSOC. M. AM. SOC. C. E.—The Committee's specifications require a crushing strength of from 16 000 to 20 000 lb. per sq. in. With ordinary granite and sand block pavements, this is not necessary. The speaker has some figures for granite showing a compressive strength of more than 35 000 lb. per sq. in. He believes that the Deval test would be beneficial. Mr. Mattimore.

Regarding the methods of construction, it is essential in block paving (not stone block alone) to specify a method of laying the blocks which will give them uniform wear.

PRÉVOST HUBBARD,† ASSOC. AM. SOC. C. E.—The speaker desires to say a word in support of Mr. Mattimore's recommendations that the hardness test be used in connection with stone blocks. It is a more rational test than the determination of the percentage of wear, inasmuch as it more nearly duplicates traffic conditions. A minimum hardness of 16, instead of the minimum percentage of wear of 4½, would be better. Mr. Hubbard.

J. W. HOWARD,‡ ESQ.—On page 2726§ there occurs the expression, "medium or fine-grained granite". This should read "uniform-grained granite free from laminations". The speaker has been making tests of granite for several cities. Granite block has excellent wearing qualities, low water absorption, and, with uniformity of grain and Mr. Howard.

* Albany, N. Y.

† Washington, D. C.

‡ New York City.

§ *Proceedings*, Am. Soc. C. E., for December, 1915.

Mr. Howard. regularity of shape combined with proper crushing and toughness tests, should be used on many streets.

The paragraph on page 2726* which reads, "the utilization of recut stone blocks has been demonstrated to be capable of producing economical and satisfactory results, and should be encouraged", is excellent. One of the best examples of this use is found at Schenectady, N. Y., where the old granite blocks on the main street were taken up, cut into four, culled, and, after the street was repaved with the recut blocks, there was enough left over to do 50% more area than that which had been taken up and thus repaved.

Concrete was used instead of the old gravel base; the blocks were cut to 4 by 4 by 6 in. On the concrete was placed a cushion of dry mixture of one of cement to three of sand. The blocks were then placed uniformly and carefully. Plenty of water was then applied, which went through and set the cushion of sand and cement. Then grout was applied twice and squeegeed into the joints. It is one of the most perfect pieces of grouted granite pavement in the United States. It was done by day labor, and cost only $1.50 per sq. yd. for everything described.

Many cities are doing the same thing. Some of the best granite quarries in the United States for making paving blocks are the old granite pavements in city streets. It is a great economy in money, first cost, and in rapidity of construction, to cut and use these granite blocks over again.

Mr. Durham. H. W. DURHAM,† M. AM. SOC. C. E.—In reference to the grain in the granite, the speaker agrees entirely with the modification in accordance with Mr. Howard's recommendation. The expression "medium or fine-grained" indicates more or less a personal opinion as to the quality of what may be a coarse grain; however, if the recommendation in the first paragraph is followed, and the blocks are properly dressed, so that they may be laid with close joints, and with accurate sides and heads—which, of course, will have to be done in order to get close joints—the question of whether the grain of the granite itself is coarse, medium, or fine, is not of much practical importance.

In the Borough of Manhattan, in the past, streets have been paved with granite from almost all the quarries along the Atlantic Coast, including those of Cape Ann, which are sometimes referred to as coarse, and from many of the quarries of interior New England, and from the South, where the granite is somewhat finer.

It may be more difficult, with one type or the other, to make the block, but, if it complies with the specifications, the result obtained can be equally good in every case.

* *Proceedings,* Am. Soc. C. E., for December, 1915.

† New York City.

Spring and Prince Streets, in the lower part of New York City, are laid with granite of somewhat coarse grain, but they present to-day one of the smoothest surfaces in the city. Near them, Lafayette and Canal Streets are paved with granites from other quarries, equally good work being done on them, and to-day it is hardly possible to detect any difference in the quality of the pavement which could be attributed to the material of the blocks. For that reason, the speaker thinks that, unless some very definite statement is made as to the quality of the granite to be used, the expression, "medium-grained and uniform" would be better. Mr. Durham.

In reference to tests, the figures given seem to be safe, and yet, as far as the speaker understands, they are not based on any very extensive tests of granite which show any material differences, that is, differences material to the best interests of the pavement. Almost any granite, from the quarries which now produce paving blocks, can be cut and laid so as to secure a satisfactory pavement under the heavy wear of New York City.

The introduction of a hardness test has been recommended, this probably meaning a test for abrasion. The speaker has made a series of tests, but was not able to determine that any of the various blocks fell into the low, or even medium, class, under the standard tests of that character; all were high, as far as hardness was concerned, and all were satisfactory. For that reason, it does not seem necessary to introduce such a test for granites; in fact, all those tested by the speaker passed the figures in the Committee's report for "percentage of wear, toughness, and crushing strength", although, among those figures, there were very great variations. Granites having all those variations have been laid satisfactorily in New York City.

The speaker is not in favor of using, on a heavy traffic street, granite blocks having a crushing strength of less than 20 000 lb. per sq. in. All the quarries which are to-day producing granite blocks in large quantities for cities in the vicinity of New York City are furnishing blocks, which, when tested, show that percentage or a higher one, in every case that has come to the speaker's attention, and he has tested a great many.

The point to be brought out is that the granite is not a manufactured product. The material is tested once, and it is not necessary to continue to test it to see that other blocks are of a similar standard, as if it were a manufactured article like steel. Consequently, the speaker has regarded tests as of minor importance for a granite from a well-established quarry. The figures adopted by the Committee as a minimum standard are satisfactory.

Mr. Mattimore has stated that he has figures relating to a granite having a crushing strength of 35 000 lb. per sq. in., and Mr. Blanchard has called the speaker's attention to the fact that, of the several tests

Mr. Durham. made of blocks coming from quarries which might supply granite for paving in large quantities, in one case the crushing strength was greater than 35 000 lb.; in one case between 30 000 and 35 000 lb.; in nine instances between 25 000 and 30 000 lb.; in eight between 20 000 and 25 000 lb.; and in seven between 15 000 and 20 000 lb.; and though the speaker made tests of a greater number of blocks than those for which he was able to find records elsewhere, he does not consider them sufficient to enable him to give an opinion on the value of the hardness test as a criterion regarding slipperiness.

About 3 years ago, there was considerable comment on the question of granite blocks, and, in connection with the New York City specifications, certain persons who were furnishing such blocks advocated minimum figures which seemed to be excessive. Before adopting such figures in the specifications, it seemed to be only proper to obtain some data as a guide. An investigation was conducted by a search in the Library of this Society and also in Columbia University, but the scarcity of tests of all kinds on granite blocks for paving purposes was surprising.

Application to the United States Office of Public Roads also elicited very little satisfactory information. That office, as a rule, does not make any tests of paving blocks, although the adoption of their standard has been urged for the New York specifications. The speaker, therefore, had tests made of samples furnished by most of the quarries which were supplying paving blocks for New York City. In addition, samples were prepared from blocks which had seen actual service during periods varying from 2 to 22 years.

The crushing tests were made on 52 cubes, and showed variations of the character mentioned by Mr. Blanchard, although there may have been a few that were less than 20 000 lb. In every case where a sample was tested, the hardness was high, above the medium, and in the very high classifications of the United States Office of Public Roads. A very exaggerated scale had to be adopted in order to show any variation at all when plotted graphically.

Included in those tests were samples from Berlin and Liverpool, and some furnished by the quarries which supplied the Liverpool blocks, and there was one specimen of Swedish granite. These were also in the same classification as to hardness; they were very uniform and high, the Berlin sample being excessively high, far above any from American quarries.

On the question of abrasion, as far as could be determined from these tests, the speaker could not, by imposing maximum or minimum limits, get any material variation between the several granites.

The recommendation for the use of recut blocks is sound, because, on a great many streets, in all the leading cities, there are large quantities of granite that can be utilized satisfactorily, under certain

conditions, as has been demonstrated in Brooklyn and in The Bronx. In the speaker's experience it has not proved satisfactory to do this in the Borough of Manhattan, because of the very inferior quality of the old granite pavements, and, more than that, the impossibility of doing it economically, as it is impractical to dress the blocks on the street on account of the traffic. The economy depends necessarily on having workshops in the streets, and avoiding long hauls; but where the blocks can be recut, the speaker believes in utilizing old stone pavements. Mr. Durham

The report states that "sand should never be used alone as a joint filler". A few lines above it is stated, "in case of temporary paving, any type of well-drained, stable foundation may be used". Sand alone, as a filler, is not suitable in American cities, although satisfactory examples of such foundations can be seen in some European cities, under certain conditions; but, in cases of temporary paving, it is frequently unnecessary to go to the expense of putting in a permanent filler.

The question of bituminous cement grout can well be left, as has been done, for future settlement, with reference to particular localities; but, in regard to what has been said as to making a smooth pavement, there are examples of bituminous filled pavements in Manhattan, and also in some other boroughs of New York City, which are as smooth as any cement grout that can be laid.

The important feature is the accurate dressing of the blocks, so that they may be laid in absolute contact, and the filler may fill the irregularities, which exist even with the best commercial blocks.

As an example of a commercial pavement with a bituminous filler, and on a grade, in comparison with the pavement in Albany that has been referred to, there is on Broadway, near 129th Street, a granite block pavement which presents a very satisfactory surface. The joints are close, and to-day, after 2 years of wear, it is virtually as smooth and in as good condition as when first laid.

E. H. Thomes,* M. Am. Soc. C. E.—Information may be recorded relative to the general physical and chemical characteristics of stone blocks, and their uniformity; also any microscopical data as to the crystalline structure, or other tests; whether the blocks wear smooth and gritty, or turtle-back and slippery, the rate of wear, the amount of noise, the ease of cleaning, etc. Many factors and conditions must be considered; some may be important and some may not, but unless proper consideration is given to each in relation to the others, it will be impossible to determine their relative weights. Mr. Thomes.

There is considerable difference of opinion as to joint fillers. A good grout filler is preferred in most cases, but where there are street openings, or it is impossible to keep the traffic off, or other

* Jamaica, N. Y.

Mr. Thomes. conditions control, it may be advisable to use a bitumen filler. Under some conditions, softer granite may give better results than that which is harder or tougher. Portland-cement grout will adhere better to a softer granite and, if the mortar has the same strength as the granite, the whole surface will wear more uniformly. Under these conditions, a pavement with wide joints may give as good results as one with close joints. With bituminous joints, a hard, tough, granite with close joints may be better, as the filler in the joints wears down, leaving the edges unsupported.

It is advisable to investigate mixtures of sand, limestone dust, chalk, cement, and other mineral matter, sawdust or other fibrous material, with asphalt, tar, or other bituminous matter, in order to make a joint filler which will be more durable and wear flush with granite block or other block pavements.

In Liverpool, the bituminous filler seemed to remain flush with the pavement surface. In that city, a truck load of sand containing about 3% of chalk or limestone dust heated at a central plant, is delivered to the street in a detachable truck which is backed up to a 1 000-gal. truck of heated tar. About equal proportions of the sand and tar are fed by gravity into a special mixing machine between the two tanks. The mixed tar and sand is wheeled to the pavement in cans similar to those used by street sweepers. It is stirred, dipped out by long-handled ladles, and poured into the joints. The chalk and sand seem to toughen the filler so that it wears better, but the quality of the tar, the care and methods used, the traffic, the character of the calks used on horses' feet, etc., are also important factors.

In Vienna, the speaker observed a 1 000-gal., portable kettle for delivering hot sand and tar mixture from a central plant. This kettle contained a mixer, somewhat like lawn-mower blades on a horizontal shaft, which was geared to the wheels to agitate the mixture when the truck was moving; the shaft also had a hand-gear to agitate the mixture when the vehicle was standing.

Some improved method of mixing and handling a bituminous filler mixture is needed in the United States.

In New York City, sand has been mixed with hot tar or asphalt in small quantities on the street and poured into the joints from small hand-pouring pots. The additional trouble and labor has increased the expense considerably above that of the ordinary tar and gravel filler. A bituminous mixture might be prepared at a central plant and delivered to the street in auto trucks, from which the filler might be spread and squeegeed over the whole surface to fill all the joints. This must be done in warm weather, otherwise the mixture would congeal too rapidly on the surface of the blocks and not fill the joints. The cost of the surplus material over the surface of the blocks would be more than compensated by the saving of labor,

and if the pavement is kept covered for a time with sand, grit, or stone chips, the surface would wear better and considerably longer. Mr. Thomes.

This matter of bituminous mixtures for the joints or beds of block pavements is still in an experimental stage, and it is an open question how much expense the results will warrant.

R. A. MacGregor,* M. Am. Soc. C. E.—For the past year a 1:3 mixture of cement and sand has been used in Manhattan for the bed. It had been proved satisfactorily that much of the settlement of the blocks was due to the washing away of the sand; in fact, there have been some very marked instances of this. Mr. MacGregor.

A sand mixture is being used in the bituminous filler, which usually contains as much as 30 or 33% of sand by volume. However, it has been difficult to keep the sand mixed with the tar, that is, to get a uniform mixture in the joints. The tar runs off, carrying the finest sand with it, and leaving much of the heavier sand in the bottom of the bucket.

The remedy for that is to make the pouring can with the spout going clear to the bottom. In that way, the sand runs out with the tar from the beginning of the operation, instead of the tar from the top of the bucket coming out first, and leaving the sand in the bottom. When the spout begins at the bottom of the bucket, it is found that the mixture is more easily put in. Some tests of the filler taken from the joints have shown a very small quantity of sand, although the average is more than 30 per cent.

Mr. Thomes has stated that, in Europe, a small quantity of fine material, such as chalk, is added. The speaker is inclined to believe that some fine dust in the mixture would be of great advantage. The difficulty is to get it incorporated. It cannot be done very well on the street, as a large percentage is blown away by the wind. The speaker tried it with trap rock screenings and got a fairly good mixture, but much of the fine material was blown away.

WOOD BLOCK PAVEMENTS.

P. E. Green,† M. Am. Soc. C. E. (by letter).‡—The Committee has dismissed too lightly the question of a preservative for wood block pavements. It is to be hoped that in its final report a more thorough discussion of this very important subject will be found. A few years ago it was thought that the use of a light oil had solved the problem of a preservative. The writer has found, however, that light oil, though it is a better preservative, has some very disadvantageous features—notably its tendency to evaporate—and he would welcome another discussion and investigation of this subject. Mr Green.

* New York City.

† Chicago, Ill.

‡ Received by the Secretary, January 3d, 1916.

Mr. Green. He is in full agreement with the Committee when it says that no necessity exists, in the case of a wood block pavement, for a resilient cushion under the blocks, and he believes that this statement should be very strongly emphasized and brought out.

The writer sometimes doubts the wisdom of any committee or association making definite recommendations as to the details of engineering construction which are not based on mathematical or scientific data, because the local situation requires such a great variation in such matters. Thus, in paving matters, the width of roadway, character of traffic, climate, grade, materials at hand, etc., etc., all should influence the selection of the material and the details of construction. Too often, if a body like the American Society of Civil Engineers makes a recommendation, it is blindly followed by some inexperienced engineer, to his later regret. Although this is recognized by this Committee, the effect is somewhat lost by a too specific recommendation in places.

Mr. Mandigo. Clark R. Mandigo,* Assoc. M. Am. Soc. C. E. (by letter).†—The statement that there is no necessity "for confining the material for wood paving blocks to long-leaf Georgia pine" is likely to be misleading, unless the few other varieties of wood, which have been used successfully, are mentioned. Attention should be called also to the fact that different woods require different methods of treatment in order to get proper penetration of the preservative. Very few woods will "take" much more than 20 lb. of preservative, and the limits can well be placed at 15 to 18 lb. per cu. ft. Thorough and uniform penetration of the preservative is essential, and, where the blocks are not treated to refusal, it is obtained only by intelligent and careful control of the treating process, the details of which must vary with the species, the density, and the seasoning of the wood used.

Wood blocks which have been in the street from 6 to 10 years are collapsing, due to a decayed center which never received any preservative. It is to be hoped that the Committee will arrive at some conclusions in regard to methods of treatment, kind of preservative, method of laying blocks, and kind of filler, to be incorporated in the next report.

There are so many points in controversy in connection with pavements that it will be impossible to conform to the ideas of all. It is desirable, however, to state what is considered good usage for the different methods which have resulted successfully and have been reasonably well defined.

Mr. Howard. J. W. Howard,‡ Esq.—If sand is used for the cushion, it should be coarse, because, if it is fine, the water which percolates down next to

* Kansas City, Mo.

† Received by the Secretary, January 14th, 1916.

‡ New York City.

railroad tracks, manholes, between the wood blocks, etc., will wash it away. The speaker favors the Portland cement-sand mixture. In London, in some cases, a cushion of asphalt or mastic of sand and a good coal-tar product is used. This prevents the water from coming up through the foundation, by capillary action or otherwise, and gathering between the top of the foundation and the bottom of the wood block. Mr. Howard

In some cases, England, France, and Germany use wood after dipping the bottom part of the blocks in hot tar just previous to laying them. That prevents water from doing much damage.

Much discussion of wood block pavements has arisen, largely because earlier wood pavements suffered so terribly in reputation in America, in Washington, D. C., Elizabeth, N. J., etc.

Wood pavements were introduced 60 years ago. The first were made under English patents. Since then wood pavements have been improved and made better and better, but there is still room for improvement.

Generally, wood must be preserved, whether the traffic is light or heavy, but where the traffic is excessively heavy, as 36 000 vehicles per day on the rue Rivoli, Paris, there is no necessity for creosoting, as the wear is so rapid that the blocks wear out long before germs could cause them to decay.

As to the preservatives for wood blocks, much information comes through the press, many articles being commercially inspired. Commercial men have certain products which they desire to market, and they advocate specifications which are calculated to help sell their wares and deter the sale of others. Therefore, engineers representing the cities and independent clients must be careful to have specifications admitting all wood pavements and preservatives which have proved to be successful. The speaker believes in straight, definite, open, comprehensive specifications, not closed, alternate, or compromise specifications.

The following are a few notes on the basic essentials for preservative or creosote oil for wood paving blocks.

Many engineers know of a specification descriptive of a certain tar product or tar-oil compound for wood paving blocks, which has appeared in some important cities and has been mentioned before this Society. This specification consists of certain tests, intended to control or limit the special "tar product" to be used to a pitch or tar containing oil, which practically excludes competition and prevents the use of good, successful, long-established, standard, distillate creosote oils. This exclusion is accomplished by specifying a heavy specific gravity of 1.08 or greater, combined with the requirement that the total distillates, up to 315° cent., shall not be more than 50% (or even 40%), and does

Mr. Howard.

not forbid stiff, brittle residues after the distillation test; whereas, some pure, good, creosote oils yield as high as 85% total distillates up to 315° cent., and some 95% up to 355° cent., have specific gravities both below and above 1.08, and leave a good, soft residue, as shown by tests of good types of excellent creosote oils of America and Europe found in reliable, authoritative books.

The English Government, having many colonies, naturally has specifications for buying materials according to standards for shipment to those colonies. In Allen's Chemistry, the specification for creosote oils for use in the English colonies is set forth, and embraces creosote oils which are good and successful.

The tests for wood preservatives should be as few and simple as possible, so that they may be made in any good laboratory and easily understood by city engineers who are not chemists. All preservatives for wood paving blocks (and there are several good ones) should be insoluble in water, and should be able to impregnate the wood thoroughly and thereby practically exclude water. The exclusion of water prevents the blocks from swelling and buckling the pavement; it also prevents fungous or germ growth, which cannot exist without water. Preservatives should have germicidal or antiseptic qualities. They should be stable, so that their essential qualities will not evaporate and leave the wood, due to the effect of the sun, air, or other elements. They should not ooze or bleed out of the wood to any noticeable extent, either from the heat of the sun or from the compression of the blocks, thereby causing a material loss of the preservative and making a pitchy, dirty pavement, the oozing or bleeding tar, such as occurs with tar products which are not distillate, true, creosote oils, being injurious to pedestrians, vehicles, floors, and carpets of adjoining buildings.

Because of their comparative cheapness and abundance in all parts of the world, by-product coal- and gas-tars are the sources from which most good distillate creosote oils are manufactured for this purpose. Within a few years water-gas tars have become the basis of manufacture of wood-preserving oils which, alone or combined with coal-tar distillate creosote oils, give promise of successful economic results. Blocks treated by this process were laid in 1912 on Arch Street, Philadelphia.

The Bethell process of wood preservation, devised in 1838, for impregnating wood with tar distillate creosote, and many modifications and substitutions thereof, such as those of Labrot, Lowry, Card, Burnett and Rueping, have been used with success for many years.

Creosote oils compose the group of the principal preservatives for wood, the best being always made by distilling tars; they are not tar products or compounds of oils and pitch, which are not distillates and are objectionable. The United States Department of Agriculture has

shown* that creosote oils are all distillates manufactured from many tars, stating it briefly as follows: Mr. Howard.

"The general process of manufacture is similar in all cases. The tar is distilled in a metal retort or still and the vapors are condensed and collected. Those distillates which are heavier than water form the true creosotes used in wood preservation."

The best creosote oils, therefore, are all distillates. A good and efficient specification admitting all good, and excluding all poor, creosote oils for wood paving blocks, should require as follows: The preservative used must be a distillate creosote oil of above 1.03 specific gravity, at 38° cent. (100° Fahr.), containing less than 1% of matter insoluble in benzol by hot extraction. It shall be water-proof, antiseptic, and contain at least 10% of crystallizable naphthalene and at least 15% of the stable anthracene oil. When distilled,† the total distillate on the basis of water-free oil up to 150° cent. (302° Fahr.), shall not exceed 1%; and the total up to 200° cent. (392° Fahr.) shall not exceed 5 per cent. The distillation shall be continued to 315° cent. (600° Fahr.), and the residue then remaining, when cooled to 25° cent. (77° Fahr.), shall be soft and easily indented with the finger. The creosote oil used shall be a distillate made from coal-tar or a combination of distillates from coal-tar and water-gas tar, provided the oil produced meets all the above tests of qualities needed for thoroughly preserving wood.

All such creosote oils contain enough naphthalene to be germicidal and prevent decay of wood. They also contain a large quantity of anthracene oil, which is water-proof, stable, and cannot be volatilized or injured by the elements and, being heavier than water, is not floated out of wood but remains, excluding water, which is the vital enemy of structural wood.

The high grades of true, distillate (pitch-free) creosote oils, used in the minimum quantity needed, even as low as 14 lb. per cu. ft. of wood, and thoroughly impregnating it, do not ooze from the wood blocks like the impure compound oils containing any appreciable quantity of pitch (the stiff, hard part of crude tars), even when such compound oils are used in as small quantities. The pitch-containing oils do not generally thoroughly impregnate the wood, and they often contain other impurities affected by water and the elements in hot, cold, or wet weather.

The citizens want clean, handsome street pavements from the beginning. Dirty, pitchy, tarry pavements should not be permitted, because it is possible, as shown by long experience in all countries, to

* "Commercial Creosotes with Special Reference to Protection of Wood from Decay", *Circular 206*, Forestry Service, 1912.

† As described in *Bulletin No. 65*, American Railway Engineering and Maintenance of Way Association.

Mr. Howard.

construct wood pavements which are clean when laid, and which remain so.

The specifications should be such as to enable a city to have durable wood pavements where needed, and, to assure competition and the lowest possible cost, they should permit the use of any kind of wood pavement which has already been shown by an experience of 10 years or more to have been successful in any city. They should not exclude those which have been proved to be durable, efficient, successful, and in good condition in actual use for a period of 10 years or more, under severe climatic conditions and heavy, numerous traffic. The broad, safe, open, single, comprehensive specification previously given is the best. It also provides for competition from every one of the good distillate creosote oils which have been successful.

One of the best descriptions and requirements for Grade 1 coal-tar creosote, referred to also as Maintenance-of-Way Oil No. 1, is that adopted by the American Railway Engineering Association, as recommended by Committee XVII, on Wood Preservation, as follows:

"The oil used shall be the best obtainable grade of coal-tar creosote; that is, it shall be a pure product obtained from coal gas tar or coke oven tar and shall be free from any tar, including coal gas tar and coke oven tar, oil, or residue obtained from petroleum or any other source; it shall be completely liquid at thirty-eight (38) degrees centigrade and shall be free from suspended matter; the specific gravity of the oil at thirty-eight (38) degrees centigrade shall be at least 1.03. When distilled by the common method—that is, using an eight (8) ounce retort, asbestos covered, with standard thermometer, bulb one-half ($\frac{1}{2}$) inch above the surface of the oil—the creosote, calculated on the basis of the dry oil shall give no distillate below two hundred (200) degrees centigrade, not more than five (5) per cent. below two hundred and ten (210) degrees centigrade, not more than twenty-five (25) per cent. below two hundred and thirty-five (235) degrees centigrade, and the residue above three hundred and fifty-five (355) degrees centigrade, if it exceeds five (5) per cent. in quantity, shall be soft. The oil shall not contain more than three (3) per cent. water."

The Committee* further stated:

"Whenever possible only Grade 1 Coal Tar Creosote should be used, and under no circumstances should coal tar be added to creosote of this grade."

As examples of good types of competing commercial creosote oils, all distillates, it is interesting to note the following specific gravities at 38° cent. (100° Fahr.): American, 1.034; another American, used at Chicago, 1.109 (these two having total distillates up to 385° cent. (671° Fahr.) of 91% and 70%, respectively, and having residues which are soft and of dark amber color); German creosote oil, specific

* *Proceedings,* Am. Ry. Eng. Assoc., Vol. 15, p. 632.

gravity, 1.064, distillates up to 355° cent., 80%, leaving soft residue; English creosote oil, specific gravity, 1.044, total distillate up to 355° cent., 90%, residue soft. Note for comparison the pitch mixture or pitch containing oil, not a distillate, which has been used for a very few years in Manhattan Borough, New York, and in other cities of the United States, but is not as good as real creosote oils. It has a gravity of about 1.115, total distillates up to 355° cent., below 60%, and the residue is hard, stiff, brittle pitch. This pitch-tar-oil-compound had 3.1% impurities, insoluble in hot benzol by the extraction test, but good creosote oils have less than 1% thus insoluble. Mr. Howard.

It is wise to put in specifications for wood block pavements direct tests to show the presence of naphthalene and anthracene oil; in other words, the specifications should have direct tests to show that the material is antiseptic and stable.

A method to ascertain the strength of wood by its density, as a measure of its quality, instead of judging by the species, has been published. The speaker thinks that the American Pine Manufacturers and the American Railway Engineering Association have adopted it. The Committee should look into the matter of judging the qualities of pine woods for paving purposes by their densities.

E. H. THOMES,* M. AM. SOC. C. E.—The speaker suggests to the Committee the advisability of including on the data forms the seasoning of the wood and the details of the treatment, as they are important factors. It should also state the average weight of treated blocks per cubic foot; the absorption of water after treatment, at the plant, and also when it should be used, as well as how timber growth rings are to be measured, the relative quantities of hard and soft wood, and the percentage of heart wood. The quantity of preservative and the character of the filler depend on several factors, one of which is the amount of traffic, whether the blocks will wear out before they rot, and whether it will be enough to crush down the tops of the blocks a little, and form a mushroom expansion joint around each block. In that case, a sand filler may be used, and where the quantity of preservative is greater there is less expansion and absorption, but if a bituminous filler is used, the quantity of preservative may be decreased. If the pavement is kept sprinkled, so that the moisture is more uniform, there is less expansion and contraction, and a smaller quantity of preservative is needed to prevent buckling. Mr. Thomes.

* Jamaica, N. Y.

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MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CLOUD CLIFFORD CONKLING, M. Am. Soc. C. E.*

DIED MAY 8TH, 1916.

Cloud Clifford Conkling was born in Rensselaerville, N. Y., on October 6th, 1862. He spent his boyhood in Scranton, Pa., where he attended the public schools.

While continuing his studies, including Civil and Mining Engineering, he obtained employment, in September, 1881, as Rodman on the Erie and Wyoming Railroad, and held a similar position, during the summer of 1882, on a water supply survey of the Ramapo Valley, N. Y.

In 1882 and 1883, Mr. Conkling took a special course of study at Williston Seminary, East Hampton, Mass.

During 1884 and 1885, he was engaged as Draftsman and Transitman in the office of an engineering firm at Scranton, Pa., and on a railroad survey in New Jersey under Mr. J. H. Rittenhouse.

In September, 1886, Mr. Conkling entered the service of the Lackawanna Iron and Steel Company (now the Lackawanna Steel Company) as Rodman in the Civil and Mining Engineering Department. He served in various positions with this Company until 1904, as follows: April, 1888, as Transitman; September, 1892, as Assistant Engineer; and February, 1894, as Chief Civil Engineer, in which capacity he had charge of the design and construction of all the civil engineering work of the Company, including the construction of its plant at Buffalo, N. Y., as well as the design and construction of all foundation work, railroad yards, sewers, villages, etc., in connection with it. As Chief Engineer of the South Buffalo Railroad, he had charge also of the design and construction of all canal and harbor works connected with that railroad.

In 1904, Mr. Conkling left the direct employ of the Lackawanna Steel Company to engage in private practice as a Consulting Engineer, in Buffalo, N. Y. In this capacity he made the surveys, plans, and estimates for the Buffalo, Depew and Lake Erie Railroad, a terminal freight line built around the City of Buffalo, and was engaged on other important work.

In 1907, the original design of the Lackawanna Steel Sheet-Piling was patented. Mr. Conkling designed and patented modifications of the original design, and was instrumental in bringing to a successful completion the designs and sections of the steel sheet-piling now rolled

* Memoir prepared by Charles S. Boardman, M. Am. Soc. C. E.

by the Lackawanna Steel Company. He also advised with engineers on many important projects in which this piling was used.

In October, 1913, the consulting work of this character had reached such proportions that Mr. Conkling returned to the employ of the Company, as Chief Engineer of the Steel Sheet-Piling Department, which position he held at the time of his death on May 8th, 1916.

Mr. Conkling's long service with the Lackawanna Steel Company, his faithfulness to duty and fairness to his associates, made for him many friends, and his death will be a severe loss, not only to his Company and friends, but also to the Engineering Profession.

He had served for 12 years in the National Guard of the State of Pennsylvania, retiring as a Sergeant-Major of the Thirteenth Regiment.

Mr. Conkling was elected a Member of the American Society of Civil Engineers on January 4th, 1905.

HERBERT WHEELER COWAN, M. Am. Soc. C. E.*

Died May 29th, 1915.

Herbert Wheeler Cowan was born in Bath, Me., on April 27th, 1862. He was the son of Augustus Nelson Cowan and Martha Jane (Chapman) Cowan, and was a descendant of the fifth generation of James Cowan, of Scotch ancestry, who came from the North of Ireland and settled in Merrimac, N. H., about 1750. His great-grandfather served for three years as a soldier in the War of the Revolution. His father was a ship-builder and store-keeper in Bath.

After a preliminary common school education in his native town. Mr. Cowan entered Worcester Polytechnic Institute, Worcester, Mass., in 1879, and was graduated therefrom with the degree of Bachelor of Science in 1882. The somewhat meager records of the Institute indicate that he was an excellent student.

From June, 1882, to January, 1883, Mr. Cowan was employed as Draftsman by Fuller and Delano, Architects, of Worcester, Mass. On March 6th, 1883, he went to St. Paul, Minn., where he joined his classmate, Mr. Fred W. Moore, and the two young engineers then proceeded as far as Winnipeg, Man., arriving there on March 29th. On April 26th, they secured employment with a contractor as Chainmen with a surveying party which proceeded westward by rail to Swift Current, then the western terminus of the Canadian Pacific Railway; thence the journey was continued on foot 450 miles to the Saskatchewan River country in the neighborhood of Edmonton, Alberta. This party was engaged in the subdivision of townships which had been laid

* Memoir prepared by Herbert S. Crocker, M. Am. Soc. C. E.

out previously by the Canadian Government. After spending the entire summer in this region and enduring the many hardships incident to frontier surveying work, Messrs. Cowan and Moore decided that they were wasting their time, and so, with seven others, they left camp early in September, walking some 200 miles south to Calgary, Alberta, which place had been reached during the summer by the Canadian Pacific Railway.

Arriving in St. Paul, Minn., on September 12th, 1883, Mr. Cowan held several temporary positions of minor importance. However, on December 10th, his career as a railroad engineer may be said to have begun, for, on that date, at Prairie du Chien, Wis., he entered the employ of the Winona, Alma and Northern Railroad Company, as Topographer, Instrumentman, and Draftsman on a preliminary survey of its line along the east bank of the Mississippi River. This line was acquired later by the Chicago, Burlington and Northern Railroad Company, and has become a part of what is now the main line of the Chicago, Burlington and Quincy Railroad between Chicago and St. Paul.

In December, 1884, Mr. Cowan was transferred to La Crosse, Wis., where he became Draftsman in the office of the Chief Engineer, the late William B. Lawson, M. Am. Soc. C. E. He remained there until July, 1886, when he was transferred by Mr. Lawson to Colorado, where he was employed as Topographer on the then contemplated extension west, from Denver to Salt Lake City, of the lines of the Chicago, Burlington and Quincy Railroad Company. In this field work, he was a member of a party, headed by Mr. T. R. Countryman, which conducted the survey between Denver and the summit of the main range of the Rocky Mountains. This work lasted until February, 1887, when, after two months' service in the office, Mr. Cowan was transferred to field work west of Salt Lake City for the same company and, until December, 1887, was engaged in reconnoitering—for the most part on horseback—a projected line to Los Angeles, Cal. He then returned to office work in Denver, which work continued until July 1st, 1888, when he received word to report, at Alliance, Nebr., to Maj. R. J. McClure, the Consulting Engineer of the Company, who made the first explorations of a railway line to extend the Burlington System to the Northwest, this being an initial step toward what was later a connection with the railways reaching to the Pacific at Puget Sound and into British Columbia. Mr. Cowan's selection for this reconnaissance was due to his splendid record on previous work of this character. His journey with Maj. McClure was made by team consisting of bronchos and buckboard, by which method of travel they covered 1 400 miles in 60 days, extending their trip through Yellowstone Park and returning to Alliance in August, 1888, at which Mr. Cowan's connection with the Chicago, Burlington and Quincy

Railroad Company ceased because of his desire to locate permanently in Colorado.

From September 1st, 1888, to April 1st, 1890, Mr. Cowan was an Assistant Engineer on the Colorado Division of the Union Pacific Railway, and from April 1st, 1890, to December 18th, 1893, he served in a similar capacity for the Union Pacific, Denver and Gulf Railway Company, a subsidiary of the Union Pacific Railway Company, in both of which positions he was engaged on construction, maintenance of way, and office work, and reported to the Division Engineer, William Ashton, M. Am. Soc. C. E.

In 1893, the Union Pacific System went into the hands of Receivers, separate Receivers being appointed for many of the subsidiary lines, and, in February, 1894, Mr. Cowan was appointed Resident Engineer for the Receiver of the Union Pacific, Denver and Gulf, and for the Denver, Leadville and Gunnison Railway Companies. He held these positions throughout the receiverships of these roads and until the reorganization of the properties, in January, 1899, into what is now known as the Colorado and Southern Railway Company. Mr. Cowan then became Chief Engineer of this company and retained that position until his death.

Of the more important work done by Mr. Cowan since 1893, mention may be made of the following:

In 1895 he had charge of the surveys and construction of approximately 27.5 miles of railway between Walsenburg and Trinidad, Colo., connecting various mine branches to form a main line between the points mentioned.

During 1900 he had charge of the plans and construction of the Colorado and Southern Railway Company's roundhouse, shops, and other terminal facilities in Denver, the headquarters of the System. In 1902, he acted as Consulting Engineer for the Fort Worth and Denver City Railway Company, in connection with the construction of the principal shops and roundhouse, as well as the yards, at Childress, Tex. During the next few years he served that company in a similar capacity in connection with the construction of terminals at Amarillo, Tex.

During 1902 and 1903, Mr. Cowan had charge of the preliminary and location surveys and the construction of 11 miles of standard-gauge line built from Fort Collins to Wellington, Colo., through an agricultural section which, at that time, was just being brought under cultivation. In 1905 and 1906 this construction was continued northward in several branches from Fort Collins, some 26 miles in all.

Also, during 1904, 1905, and 1906, Mr. Cowan acted as Consulting Engineer in connection with the surveys and construction of approximately 300 miles of standard-gauge line for the Trinity and Brazos Valley Railway Company, between Cleburne and Teague, Tex., and

also between Waxahachie and Houston in the same State. This line had the joint financial support of the Colorado and Southern Railway Company and the Chicago, Rock Island and Pacific Railway Company, and was constructed under the joint direction of their Engineering Departments.

From 1906 to 1908, inclusive, he located and constructed approximately 17 miles of second track paralleling the main line of the Colorado and Southern Railway between the northern limits of Denver and extending northwestward to Louisville Junction. This work involved a reduction of gradient from 1.25 to 0.8 per cent. A portion of this road is operated by the Denver and Interurban Railroad Company as an electric line.

From 1908 to 1910, Mr. Cowan served as Consulting Engineer in the construction of 83 miles of standard-gauge line known as the Stamford and Northwestern Railway, extending northwestward from Stamford to Spur, Tex.

For some years prior to 1910, the increasingly heavy traffic on the 46 miles of main line of the Denver and Rio Grande Railroad Company between Minnequa and Walsenburg, Colo., which had been operated jointly by that company and the Colorado and Southern Railway Company, rendered it necessary to take steps to relieve the congestion. Accordingly, under the joint supervision of Mr. Cowan and Mr. J. G. Gwyn, Chief Engineer of the Denver and Rio Grande Railroad Company, surveys were made, which resulted in the construction, during 1910 and 1911, of a new line providing a double track of lighter curvature and much lower gradient. This at the present time is one of the heaviest pieces of railroad construction in Colorado; the line has been operated with great satisfaction to both the companies interested.

During 1910 and 1911 there was also constructed, under the direction of Mr. Cowan as Chief Engineer, a standard-gauge line, having a length of 32 miles, between Dixon, Colo., and Cheyenne, Wyo.

From 1908 to the time of his death, as a member of engineering boards directing their construction, Mr. Cowan was actively interested in a number of local improvements in Denver, among which were the Twentieth Street Viaduct, the West Alameda Avenue Subway, and the Colfax-Larimer Viaduct, in all of which public improvements his company, with other corporations, was interested financially.

Owing to his marked ability in handling joint work satisfactorily, together with his profound knowledge of the local railway and terminal situation, Mr. Cowan was chosen in 1912 as Chairman of an Engineers' Committee, composed of the Chief Engineers of all the holding companies constituting the Denver Union Terminal Railway Company. This Committee had charge of all the engineering work pertaining to the remodeling of the Denver Union Station, and the construction

of its trainsheds, together with the re-arrangement of the passenger and terminal yards, and incidental work in connection therewith. This work involved the harmonizing of the different interests, as well as the handling of intricate details, and was only half completed at the time of his death.

In his professional life, Mr. Cowan was noted for the thorough manner in which he handled his work and for his retentive memory in connection with its details. He did not confine his attention to the duties of his own department, for, owing to his good judgment, he was constantly called into council with the executive heads of his company relative to general policies and administration. He took a great interest in the development of the resources of the country tributary to his road, and was instrumental in the projection and construction of many miles of spurs to stone quarries and coal and metalliferous mines.

On account of his honesty, good judgment, and breadth of view, his services were often sought, both in consultation relative to new projects and in the arbitration of differences of opinion.

At the time of his death, he was a Director of the Colorado Railroad Company and of the Denver and Interurban Railroad Company, both subsidiaries of the Colorado and Southern Railway Company.

On July 20th, 1893, Mr. Cowan was married to Sarah A. McMillan, who died on April 15th, 1897. On June 30th, 1898, he was married to Mrs. Clara (Lewis) Waterman, by whom he is survived. The surviving children of this marriage are Ralph Dudley and Lester Augustus Cowan.

A description of Mr. Cowan's life would be incomplete without mention of the many excellent qualities which won him the love and respect of all with whom he came intimately in contact. He was generous, fair-minded, and unselfish in securing advancement of his employees and members of his Profession. Being charitable in his judgment and opinion of others, it is not strange that, although he insisted on work of first quality, he did not arouse the enmity of those whom at times he found it necessary to oppose. Although retiring in disposition, he had many intimate friends, not only in Colorado, but throughout the country, all of whom were greatly shocked at his taking off in the prime of life and at the time when his usefulness in his community and among his circle of friends was ever increasing.

In August, 1900, Mr. Cowan became a Charter Member of the American Railway Engineering Association, the annual conventions of which he attended with regularity and, from time to time, he contributed valuable information to its Standing Committees.

On April 1st, 1914, he became a Corporate Member of the American Wood Preservers' Association, in which he took a very active

interest. That Association, at a recent convention, passed resolutions of regret on his death.

Formal resolutions extolling the life and services of Mr. Cowan were adopted by the Board of Commissioners of the City of Fort Collins, Colo., and by the Board of Directors of the Colorado and Southern Railway Company.

Mr. Cowan was elected a Member of the American Society of Civil Engineers on June 3d, 1908, and, in 1909, he was one of the local members active in the formation of the Colorado Association of its members.

WILLIAM WALLACE FOLLETT, M. Am. Soc. C. E.*

Died December 28th, 1915.

William Wallace Follett was born in New Sharon, Me., on September 22d, 1856, and was graduated from the University of Michigan in June, 1881. His college course was completed on a minimum of borrowed money, and only a strong will power, which characterized all his life of hard work, enabled him to persist in order to obtain his degree.

After his graduation, Mr. Follett began work on the location of the New Orleans and North Eastern Railroad, in the swamps of Louisiana, where he had to lead a crude existence, combating unpleasant forces in an unwholesome climate. For 3 years he was in charge of a "Residency" of 13 miles of grading on that road. He next took charge of the construction of a highway and railroad bridge across the Red River for the Vicksburg, Shreveport and Pacific Railroad. Afterward, for the same Corporation, he had charge of the erection of some roundhouses, depots, etc., and also of field work in remodeling the Shreveport Yards. Later, he was engaged in levee work and the study of rectifying the channel of the Red River below Shreveport.

In March, 1886, Mr. Follett was employed by the Atchison, Topeka and Santa Fé Railroad on topography, and afterward was placed in charge of the construction on one of the divisions of that line. He completed the grading on two divisions of 15 miles each, and established the grade line on the Ottawa-Emporia Division. He also located all except about 16 miles of the Denver-Pueblo Line, and made surveys for the Denver Terminals and for about 350 miles of preliminary lines and about 60 miles of location in Colorado.

In November, 1887, Mr. Follett was given command of the construction forces, finishing up the yards, etc., of the Denver-Pueblo Line, and in May, 1888, he took charge of the drafting-room of the

*Memoir prepared by Stuart Henry, Esq.

Fuel Department, at Topeka, Kans. In 1889, he returned to Denver and made topographical surveys, plans, and an estimate of cost for a summer resort, the work for which was carried out and proved successful. In that and the following year, he was with the United States Geological Survey as Division Engineer on irrigation surveys. He made the preliminary surveys, maps, plans, and estimates of cost for the "International Dam" and reservoir at El Paso, Tex., completing also the reconnoissance of the Rio Grande drainage, hunting and segregating reservoir sites.

In 1890, Mr. Follett took up general engineering work at Denver and located 25 miles of a rather difficult line for the Perry Park Railroad. From 1890 to 1892, he was Assistant Engineer of the Artesian Underflow Investigation, United States Department of Agriculture. He next devoted his energies to general engineering work, examinations, and reports of irrigation schemes, a design for a private water supply system, and also completed extensive mineral surveys in New Mexico.

In 1893 he located a canal for Col. Nettleton on the Yaqui River. In 1894, he was appointed Engineer in charge of the "Delgany Street Public Sewer Extension," in Denver, and during the next year located a railroad from Flagstaff, Ariz., up the Grand Canyon. In 1896 he was Consulting Engineer for the Dodge City (Kansas) Irrigating Canal, and wrote an exhaustive report on the water conditions of the Upper Arkansas River in Kansas.

Mr. Follett was appointed, in March, 1897, Consulting Engineer for the International (Water) Boundary Commission, United States and Mexico, and held that position until April, 1900, when he resigned and went back to Denver, whence he was immediately called to Topeka to make an appraisal of the water-works. He next put in a pipe line, 20 miles long, to furnish water to Prescott, Ariz., and also did work for Gen. Palmer at Colorado Springs.

He was re-appointed Consulting Engineer for the International Boundary Commission on the Mexican border early in 1902, which position he held until July, 1914. In 1906, he was selected as Consulting Engineer for the United States Reclamation Service. In 1907, he had expert charge of an irrigation project on the Pecos River for the United States and Mexico Trust Company. He made a hydrographic investigation, in 1913, for the El Paso and Southwestern Railroad, for the supply of water for its pipe lines near Carrizozo, N. Mex.

In June, 1914, the University of Michigan conferred on Mr. Follett the honorary degree of Master of Engineering for eminence as an irrigation engineer and especially for his work on the Mexican Boundary, for no one could speak with such authority as he on the subject of the equitable distribution of the waters of the Rio Grande. At about this time he was appointed Consulting Engineer for the Elephant

Butte Water Association and the El Paso Water Users Association, which together had plans for irrigating some 185 000 acres of land under the Engle Dam, then nearing completion, but he was unable to accept this position on account of ill health.

Mr. Follett delivered many public addresses in the West on irrigation, water supplies, and the rights of States, different valleys, and communities to the use of various western waters. Throughout the Rocky Mountain region he was a recognized authority on this large and difficult subject. He was frequently called to Washington for expert advice.

When Mr. Follett stepped down from the International Boundary Commission on July 1st, 1914, his days had long been numbered. Many medical experts in all parts of the country were consulted as to his distressing physical condition, but with little avail. He weakened rapidly, and died at his home in El Paso, Tex., on December 28th, 1915. In July, 1915, a letter to the writer contained the following:

"I am all in, old Pard, and you will never see me again. How long I will linger I can't say. I suffer all the time, and won't be at all sorry when the time comes for me to go."

Although his years were frequently beset with obstacles which would have daunted feebler souls, Mr. Follett never faltered in his dogged pursuit of whatever task or aim was before him. Blessed with a tough physique as a young man, he readily sacrificed himself to any conditions of toil, often living under unsanitary conditions and with improper food, as he whipped himself on to his many separate tasks.

These early hardships and deprivations after a time affected his health, so that the last twenty years of his busy career were passed under an almost steady strain of pain, more or less acute, while he hung on to his duties with unflinching courage. The writer has seen him at work over reports day after day with a big bottle of ugly looking medicine standing by his manuscript. A frequent dose from the bottle would assuage his suffering sufficiently to enable him to prosecute his labors.

This physical and moral heroism was equalled by his incorruptible honesty as to fact and opinion. He could not be bought or influenced. He declined many a promising job, because he did not believe it served the truth or an upright end.

Mr. Follett was a keen judge of human nature, and possessed a lively sense of humor. He would resolutely pass off most despairing situations in his work with a brave jest, and lose little delay in regrets and repining. He was fond of chess, and derived the utmost pleasure from attending the theater whenever he was in New York City.

In 1888, he was married to Helen Jordan at Pueblo, Colo., who, with two sons, William L., Hydrographer, United States Reclamation Service, at El Paso, Tex., and Leslie C., aged sixteen, survives him.

Mr. Follett contributed in high measure to the renown of the Engineering Profession. He had resistless energy, was relentless in logic, and never shirked the smallest detail. He was a valuable, courageous, and public spirited man, wholly devoted to his family, and would divide his last crust with any friend.

Mr. Follett was elected a Member of the American Society of Civil Engineers on July 5th, 1893.

CARL ROBERT GRIMM, M. Am. Soc. C. E.*

Died February 15th, 1916.

Carl Robert Grimm was born on May 3d, 1849, at Neuwied-am-Rhein, Germany. He was graduated from the Royal Prussian Gewerbeschule in Coblenz, in 1869. After serving in the Franco-German War of 1870-71, he entered the Polytechnic School at Aachen, and finished his studies in 1875 at the University of Berlin.

After one year as a Locomotive Draftsman, Mr. Grimm was engaged, in the service of the German Government, at Strassburg, in working out designs for plate girders and in experimenting on building materials for railroads.

In 1881, Mr. Grimm came to the United States and began his career as a Bridge Engineer as Draftsman with the Phœnix Bridge Company at Phœnixville, Pa. He was afterward employed with the Dominion Bridge Company in Montreal, Que., Canada; the Wrought-Iron Bridge Company in Canton, Ohio; and the Mount Vernon Bridge Company in Mount Vernon, Ohio.

In 1890, he was appointed Engineer with the Tacony Iron and Metal Company, of Philadelphia, Pa., and while in the service of this Company designed the steel framework which caps the tower of the City Hall in Philadelphia and supports the bronze statue of William Penn.†

From 1895 to 1897, Mr. Grimm was employed, as Designing Engineer, by the New Jersey Steel and Iron Company, of Trenton, N. J., and from 1898 to 1901 by the Elmira Bridge Company, Limited, of Elmira. N. Y. As Engineer of this Company, he designed the Kinzua Viaduct on the Erie Railroad at Bradford, Pa.‡ In 1907-08, he was employed by the Pennsylvania Steel Company.

In 1908, Mr. Grimm came to New York City, where he continued to reside until 1913, when he went to Europe. During this time, in

* Memoir prepared by John C. Trautwine, Jr., Assoc. Am. Soc. C. E., supplemented by material on file at the Society House.

† "The Tower of the New City Hall at Philadelphia, Pa.", by C. R. Grimm, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. XXXI, p. 249.

‡ "The Kinzua Viaduct of the Erie Railroad Company", by C. R. Grimm, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. XLVI, p. 21.

1904 and, again, in 1908, he was in the service of Gustav Lindenthal, M. Am. Soc. C. E., whom he assisted in the design of the Hell Gate Bridge and other structures for the New York Connecting Railway. He was also engaged in literary work, his book on "Secondary Stresses in Bridge Trusses", having been published in 1908.

On his return to Europe in 1913, Mr. Grimm settled in Paris, France, where he was engaged in consulting work until 1914 when he went to Neuwied-am-Rhein, Germany, where he died after a short illness. He is survived by his widow, who is a native of the State of Ohio.

Of Mr. Grimm, Mr. Lindenthal writes as follows:

"He had a strong sense of duty and loyalty to his work; he was exceedingly painstaking and particular in his method of work, and had a rare sense of order. He had great merit as a designing engineer, particularly of structural details, in which his ideas were often original and always carefully worked out to the last rivet.

"His work on 'Secondary Stresses in Bridge Trusses' is witness of his painstaking analysis of theoretical niceties and of his great usefulness in modern designing.

"He had been a most valuable assistant to me, and I was sorry when he made up his mind to withdraw from regular office work and give more attention to his personal affairs."

Besides his papers on the City Hall Tower at Philadelphia, Pa., and the Kinzua Viaduct, Mr. Grimm also contributed one entitled "The Arch Principle in Engineering and Esthetic Aspects, and Its Application to Long Spans",* which was presented before the Society on November 2d, 1910.

Mr. Grimm was elected a Member of the American Society of Civil Engineers on June 4th, 1890.

FREDERICK WILLIAM DOANE HOLBROOK, M. Am. Soc. C. E.†

Died April 13th, 1916.

Frederick William Doane Holbrook, the son of Edward Ridgeway and Frances Louise (Doane) Holbrook, was born on Beacon Hill, Boston, Mass., on January 26th, 1840. He was educated in the public schools of his native city, taking a Franklin Medal at the Adams School, and the Abbott Lawrence Prizes in French and mathematics at the English High School.

Professionally self-taught in great measure, Mr. Holbrook's education was enriched and enlarged through an intense thirst after knowledge, which led him, at all times and everywhere throughout his life,

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* *Transactions*, Am. Soc. C. E., Vol. LXXI, p. 233.

† Memoir prepared by Frank O. Maxson, M. Am. Soc. C. E.

to seek information beyond that applicable to or offered by the work on which he was immediately engaged. He was, therefore, never at a standstill, content with present attainments, but was reaching forward to new acquirements in order that he might the better perform the duty of to-day and be prepared for that to which he might be called to-morrow.

In consequence, the positions which he filled have been important, and, in each, we find him doing his work patiently, carefully, earnestly, and conscientiously, faithful always to the charge committed to his trust. The record of his services which follows, covering an active professional life of fifty-five years, is one in which he rightfully took pride.

He began his engineering work in the office of the late Thomas Doane, M. Am. Soc. C. E., a civil engineer of Boston and Charlestown, Mass., and, in 1861, became Assistant Engineer of the Old Colony Railroad, with an office at Fall River, Mass. When the Civil War broke out, he enlisted at once, and served with his regiment until, his ability coming to the notice of the Secretary of War, he was, by special order of that officer, transferred to the Engineering Department engaged in the construction of the defenses of the City of Washington.

Resuming the practice of his profession on his discharge in 1865, Mr. Holbrook was employed as Resident Engineer at the east end of the Hoosac Tunnel for two years, when he became Division Engineer of the Lebanon Springs Railroad in Vermont in 1867, of the Burlington and Missouri Railroad in Iowa in 1868, and Assistant Chief Engineer and Superintendent of the latter road in 1869, continuing as such until 1874, when he was appointed City Engineer of Plattsmouth, Nebr.

Recalled to the East, he served as Division Engineer of the Troy, Greenfield and Hoosac Tunnel Line, with an office at Shelburne Falls, Mass., in 1875-76. He was then appointed Assistant Engineer of the Boston Water-Works, at Framingham, Mass., a position which he filled from 1876 to 1879.

Returning to the West, Mr. Holbrook was employed from 1879 to 1888 on the Northern Pacific Railroad, as follows: as Principal Assistant Engineer, at Mandan, N. Dak., in 1879-80; as Locating Engineer, 1880-81; as Division Engineer, Wisconsin Division, Superior, Wis., 1881-84; as Lease Agent, St. Paul, Minn., 1884-86; and as Division Superintendent, Yellowstone Division, Glendive, Mont., 1886-88.

The farther West called him, however, and, in 1888-89, he was employed as Principal Assistant of the Seattle, Lake Shore and Eastern Railway and S. E. Construction Co., at Seattle, Wash., becoming Manager of the railroad in 1889-90. Afterward, he served for two years as Secretary of the Board of Public Works of the City of Seattle, Wash.

On December 5th, 1892, Mr. Holbrook entered the Government Service at the Puget Sound Naval Station as Principal Civilian Assistant, and continued his work as such during the ensuing twenty-three years, during which time the Station developed from a wilderness to a fully equipped Navy Yard, with piers, dry docks, shops, water-works, and all other appliances, second to none. From 1898 to 1903, he was in charge of all engineering work at the Station, and from 1899 to 1901 was Acting Head of Department, and, as such, planned and constructed the improvements of those years.

During the later years of his life, Mr. Holbrook's health seriously declined, mainly through an accident received while on duty at the Navy Yard, but his indomitable will and nervous energy kept him steadily at work, performing his duty as if there was no such thing as failing bodily strength. Retaining in full power his mental vigor, he labored with all the push of youth in the accomplishment of work given him to do, and it was only a few weeks before his death that he felt compelled to resign the position he had filled so long and so acceptably, because he could no longer make his enfeebled body obey his will.

The writer's intercourse with Mr. Holbrook during the time that they were together at the Puget Sound Naval Station—somewhat more than a year—was rather that of friend with friend than of principal and subordinate. He was an older man than the writer, with broader experience and knowledge, and was unfailing in devotion to duty, ever ready to undertake and perform, capable, intelligent, and faithful. Given something to do, he did it, without watching, without urging. He made each job his own, to be done in the best way, in the least time, and at the least expense, considering the end in view in its performance. It is no wonder then that he was relied on, trusted, and believed in by every one with whom he had to do, whether employer or employed. From their first meeting the writer can recall no time when there was a veil of formality between Mr. Holbrook and himself. The work proposed, planned or ordered, was talked over as those discuss subjects in which they are mutually interested, and so the friendly official association soon extended to personal matters, and there grew that happy sense of fellowship which the passing years left unbroken. The writer feels assured that his experience has been that of every one who knew Mr. Holbrook; that everybody who met him, in public or in private, found him a Man.

On Mr. Holbrook's seventy-sixth birthday, on January 26th, 1916, which was also the birthday of his wife, the office force of the Puget Sound Navy Yard, Department of Public Works, in which he had been continuously employed since December 5th, 1892, until his resignation a few days previous, on account of ill-health, sent him a large box of beautiful flowers, and with it a letter signed by officers and

men alike, embodying a very flattering address concerning his services in the past, and their best wishes for his future happiness and health. This genuine expression of good will and appreciation touched Mr. Holbrook's heart, and, in a letter to the writer, after reference to this incident, and after stating his endeavor always to assist all who came to him, he continued:

"I recognize that the only permanent satisfaction obtained in life is that due to helping others even in small matters, and also how little it takes to gratify both those of tender years, and the aged, who are so often neglected."

And this satisfaction Mr. Holbrook deserved and received.

Mr. Holbrook was a charter member of the Pacific Northwest Society of Engineers; a member of John F. Miller Post, G. A. R.; of St. John's Lodge, No. 9, F. and A. M.; of Seattle Chapter No. 3, Royal Arch Masons; and of Seattle Commandery, Knights Templar. He belonged to the Old School Boys Association of Boston, Mass., and was eligible for membership in the Sons of the American Revolution. His funeral was held under the auspices of the Masonic Fraternity.

He was married to Miss Nellie J. Barker, at Medford, Mass., on August 14th, 1862, and is survived by his wife, two sons, Paul and Fred. P., and by a daughter, Jennie, all of Seattle, Wash.

Mr. Holbrook was elected a Member of the American Society of Civil Engineers on October 6th, 1886.

WILLIAM EDWIN HOYT, M. Am. Soc. C. E.*

Died April 2d, 1916.

William Edwin Hoyt, son of Alfred Metcalf and Harriet Fabyan Hoyt, was born in Portsmouth, N. H., on July 3d, 1845. He was fitted for college at Phillips Exeter Academy, and was admitted in 1865. Becoming dissatisfied with a strictly classical collegiate course, however, he left at the end of his Sophomore year and entered the Massachusetts Institute of Technology, where he continued his engineering studies through the regular course, and was graduated in June, 1868, with the degree of Bachelor of Science in Civil Engineering.

Mr. Hoyt had his first experience in professional work several years before he began his studies at the Institute. During his summer vacations, while at the Academy and in college, he was employed on the Government fortifications which were then building at the entrance of Portsmouth Harbor, his father having charge of this work under Col. J. N. McComb, of the United States Army Engineer Corps. For

* Memoir prepared by George W. Kittredge, M. Am. Soc. C. E., and others connected with the New York Central Railroad Company.

the protection of the harbor and adjoining coast, three forts were built, Fort Constitution, Fort McClary, and another extensive earthwork on the east side of the Piscataqua River, and the experience gained in this work of massive construction was of great value to the young engineer.

Mr. Hoyt's connection with railroad work began in 1868, on the Chicago, Burlington and Quincy Railroad, where he was employed for a considerable time in making surveys for branch lines. Afterward, he was sent to take charge of building an important extension in Iowa. On its completion he returned to Illinois and built two divisions of the Dixon, Peoria and Hannibal Railroad, a subsidiary of the Burlington. Mr. Hoyt was then engaged for some time in the examination and inspection of new railroads which had been built for the Chicago, Burlington and Quincy Railroad in Illinois and Iowa.

In 1873, at the time when activity in railroad building had in some degree abated, Mr. Hoyt went to Europe in order to familiarize himself with English and Continental engineering practice and study the best examples of engineering work abroad. Considerable time was spent in England, Austria, Switzerland, Italy, and France, especially in the mountainous districts, where railroad building had been attended with unusual difficulties on account of great natural obstacles.

After gaining valuable knowledge and experience in this manner, he returned to the United States and established himself as a Civil and Consulting Engineer in Boston, Mass. He soon received an offer from the Massachusetts Institute of Technology to devote part of his time to the instruction of students of the Engineering School, and the Departments of Field Engineering and of Bridge and Roof Construction were put into his hands. In addition to the regular outside work of his office, Mr. Hoyt superintended these Departments of the Institute for several years, until other matters demanded his attention away from Boston, and he was obliged to devote himself to more active occupation.

In 1880, Mr. Hoyt was employed to inspect railroads in Canada in the interest of Eastern capitalists, and, subsequently, he entered the services of the Lake Erie and Western Railroad as Locating Engineer of its contemplated branch from the main line to St. Louis, Mo.

Early in the spring of 1881, before the Lake Erie and Western surveys were completed, Mr. Hoyt was appointed Chief Engineer of the Buffalo, Rochester and Pittsburgh Railway Company, in charge of construction and maintenance, and this position he held for almost twenty years. Under his administration, important extensions of the road in New York State and in Pennsylvania were surveyed and built, increasing its length more than threefold, with a corresponding gain in carrying capacity and earning power.

In 1900 Mr. Hoyt entered the service of the New York Central and Hudson River Railroad Company to take important assignments in the Engineering Department.

In 1901, he was sent by the National City Bank to Mexico to study the railway systems and make a detailed report on their condition, their capacity, and their prospects.

In 1905, he was sent to the International Railway Congress in Europe as an official representative of the New York Central Lines, and made an extended contribution to the discussion of that body.

During Mr. Hoyt's connection with the New York Central Railroad in his later years, he occupied a unique position. His thorough knowledge of railroad affairs and his broad and comprehensive treatment of his subject made him a particularly valuable expert witness for the Company in any matters involving its relations, not only with municipalities, but with State and Government commissions. His grasp of detail and his accuracy were remarkable for a man of his advanced age.

Mr. Hoyt served as Health Commissioner of Rochester, N. Y., from 1892 to 1897. He was a member of the American Railway Engineering Association, the Society of Colonial Wars, and the National Geographic Society. In Rochester, he was a member of the Genesee Valley Club, the Country Club, and the Fortnightly Club, and, in New York City, of the Transportation Club.

In 1876, Mr. Hoyt was married to Susan Rogers White, of Boston, Mass., who, with two children, Dr. C. Wentworth Hoyt and Mrs. C. Henry Mason, both of Rochester, N. Y., survives him.

Mr. Hoyt had a host of friends and few enemies. He was a man of extraordinary personality, combining a hearty geniality with an inborn sense of personal dignity. His sense of humor was a delight to his friends; and his counsel was much sought.

His eager, reverend curiosity concerning life and its meaning and possibilities, which grew in his mind with the passing years; his candor of spirit, which came to shine ever whiter and clearer as that spirit found refinement by life's experience, and truth came ever to be more loved and error to be more despised; the integrity of character which the long years of honest-mindedness and faithful work developed; and his wealth of friendliness, which accumulated with the growing knowledge of the years, justly earned for him his enviable reputation.

In every aspect of his vigorous and useful life Mr. Hoyt gave the utmost of those sterling qualities which formed his remarkable personality.

Mr. Hoyt was elected a Member of the American Society of Civil Engineers, on March 5th, 1884.

JOHN HOWARD JOHNSTON, M. Am. Soc. C. E.*

Died May 8th, 1913.

John Howard Johnston died suddenly in Lima, Peru, on May 8th, 1913, at the age of about 63. Born in America, he served, as a boy, in the Civil War. Subsequently, he entered the Scientific Department of Dartmouth College, from which he was graduated in the Class of 1870.

In September, 1870, he was engaged on the construction of the Westfield and Holyoke Railroad, of Massachusetts, and afterward served as Draftsman with the Hartford and Saybrook, or Connecticut Valley, Railroad.

In March, 1871, Mr. Johnston went to Peru, where he was employed on the location and construction of several railroads, among which were the Arequipa and Puno Railway, the Jaliaca and Cuzco Railway, the Lima and Oroya Railway, etc.

A few years after his arrival in Peru, Mr. Johnston entered into partnership with the late Mr. Jacob Backus and started the Backus and Johnston Brewery at Lima. This business proved a great success, and about 1890 was sold to an English Company.

Being full of energy, Mr. Johnston was not satisfied to retire from business, and he and Mr. Backus began mining and concentrating at Casapalca, Peru, about 14 000 ft. above sea level. At that time, as the railroad did not reach Casapalca, all the machinery for the plant had to be transported by mule. It was work of this arduous kind which especially appealed to Mr. Johnston.

After six years, having developed his mining and smelting interests there into a profitable business in which he still retained his interest, he left Casapalca and retired to Southern France. Automobiling was then in its infancy, and motoring became Mr. Johnston's principal hobby. He was the inventor of the Xenia carbureter.

Mr. Johnston spent several years between Paris and his villa at Cimiez, but, in 1909, his restlessness took him again to Peru. He constructed at Casapalca a modern smelter which now produces 8 000 tons of copper and 3 000 000 oz. of silver annually. He became so interested in his work there that for three years he never left the place. At his age, the high altitude eventually undermined even his iron constitution, for, after an apparently slight illness, he went down to Lima where he died on May 8th, 1913, quite suddenly, in his sleep.

Mr. Johnston's energy and genial manner endeared him to all who came in contact with him, and few foreigners in Peru have been more respected and admired by the Peruvians.

* Memoir prepared by Henry Cachard, Esq., Paris, France.

He introduced two industries in Peru—brewing and smelting—and, in spite of the natural difficulties of the country, he made a great success of both.

Mr. Johnston was elected a Member of the American Society of Civil Engineers on March 1st, 1876.

HENRY COATHUPE MAIS, M. Am. Soc. C. E.*

Died February 25th, 1916.

Henry Coathupe Mais was born at Westbury-on-Trym, near Clifton, England, in 1827. He was educated at a private school in Bath and at the Bristol and Bishop's Colleges, respectively, at Bristol, England, and completed his studies under the tutorship of Mr. John Exley, of Cambridge, England.

In 1844, Mr. Mais was articled as a pupil to Mr. William Michael Penistone, one of the Chief Engineers under Sir I. K. Brunel, during the completion of the Bristol and Exeter Railway, and, subsequently, on the surveys and construction of the Wilts, Somerset, and Weymouth Railways. On this work Mr. Mais had every opportunity of gaining a thorough knowledge and training in the principles and practice of railway location and construction. After completing his articles he went to Birmingham where he spent 18 months in the Engineering Department of the Broad Street Foundry.

In June, 1850, Mr. Mais, with the proprietor of the Broad Street Foundry, purchased a large assortment of engineering tools, patterns, and machinery, and went to Sydney, New South Wales, Australia, with the intention of establishing an engineering and manufacturing business there, but the discovery of gold on the Turon River and at other localities, almost immediately after their arrival in that country, unsettled business to such an extent that they were compelled to abandon their original intentions.

In 1851, Mr. Mais accepted the position of Engineer to the Sydney Railway Company which had been formed to construct the line from Sydney to Parramatta. He held this position for 18 months and then entered the service of the City Commissioners as one of the Assistant Engineers where he remained until 1856, when he joined the late E. D. Nicolle, in a manufacturing and general engineering business in Sydney, and carried out some extensive mechanical work, among which was the erection of the first hardwood sawmills at Ourimbah, near Gosford, New South Wales.

In June, 1858, Mr. Mais went to Victoria where he was engaged as Engineer and Manager for Cornish and Bruce, the Contractors for the

* Memoir prepared by the Secretary from material on file at the Society House.

construction of the Melbourne to Bendigo Railway, first on Sections 2 and 3, and, subsequently, on Sections 4, 5, and 6, which were completed in 1862.

He was then appointed Engineer and Manager of the Melbourne and Suburban, and of the Brighton Railway Companies, the lines of which extended from Melbourne to Hawthorn and Brighton Beach, respectively. He retained this position until June, 1866, when these companies and the Hobsons Bay Railway Company were amalgamated, and the whole system became the property of the State.

In 1865, Mr. Mais had been appointed by the Victorian Government as a member of a Board of Inquiry to investigate matters connected with building contracts for the Kew and Ararat Lunatic Asylums, and also as a member of a Board of Experts to examine into and report on the value of private wharf frontages, buildings, etc., on the north bank of the River Yarra, with the view of the purchase of these properties by the Government. He was also one of three engineers appointed by the Tasmanian Government to examine and report on the construction of the main line railway between Launceston and Hobart, which report was to enable that Government to ascertain whether the Railway Company in question had carried out its undertaking in a manner such as would entitle it to payment of interest guaranteed by the Government.

In 1866 Mr. Mais entered the Victorian Water Supply Department, where he remained until April, 1867, when he accepted the position of Engineer-in-Chief of South Australia, an office which he held continuously for 21 years until he resigned in 1888. During these years, in addition to this position, Mr. Mais held the following appointments: General Manager of Railways, including charge of the Maintenance and Locomotive Departments, from 1867 to 1879; Engineer of Water-Works from 1867 to 1878; and Engineer of Harbors from 1880 to 1888. He also constructed 1 473 miles of railway; 8 000 lin. ft. of wharves and jetties; built several first and second-order lighthouses; erected the fortifications at Glanville and Largs Bay, Port Adelaide; and had general charge of public works and roads outside District Councils, involving altogether an expenditure of £10 500 000. He had also served as a Justice of the Peace for South Australia for more than 34 years.

In December, 1882, under the direction of the Government of South Australia, Mr. Mais made a tour around the world, which extended over nine months, visiting Ceylon, Italy, Switzerland, France, Great Britain, and the United States, and returning to Sydney *via* San Francisco, Cal. On his return in 1883, he embodied his observations in a report which was published and laid before Parliament, and for which he was granted a special sum of £815.

On his retirement from the office of Engineer-in-Chief of South Australia in 1888, Mr. Mais returned to Melbourne and engaged in private practice as a Consulting Engineer and Arbitrator, in which

latter capacity he acted in important disputes between railway contractors and the Governments of Victoria, New South Wales, Queensland, and Tasmania, respectively. In 1891, he was offered the position of Engineer-in-Chief of West Australia, but declined, in order to continue his consulting practice.

Among the works carried out by Mr. Mais were the following: Inspecting private railway lines in South Australia; designing and erecting a hydraulic sluicing plant for gold mining; from 1895 to 1897, Inspecting and Consulting Engineer in Victoria for extensive gold milling and mining machinery for West Australia; and from 1900 to 1902 as Consulting Engineer for the Charlotte Plains Electric Transmission Company, the New Havillah, Charlotte Plains, and Junction Deep Leads of the Victoria Gold Mines, on the erection of extensive steam and electrical machinery for power purposes. In 1902, he was appointed and served as a member of a Committee to test and report on the merits of certain locomotive spark-arresting appliances for the Victorian Government.

In 1912, after having been in active practice in Melbourne, Victoria, as a Consulting Engineer for nearly 25 years, Mr. Mais, owing to ill-health, retired to his home in South Yarra, Melbourne, where he died on February 25th, 1916.

He was elected a Member of the Society of Engineers, London, in 1873, and a Member of the Institution of Civil Engineers, London, in 1879, having held the position of Chairman of the Victorian Advisory Committee of that Society since 1890. He was also a Member of the Institution of Mechanical Engineers of London, England.

Mr. Mais was elected a Member of the American Society of Civil Engineers on June 6th, 1883.

CHARLES HENRY PRESTON, M. Am. Soc. C. E.*

Died April 20th, 1916.

Charles Henry Preston, the second son of Aaron Lee and Susan M. Preston, was born on Bundy Hill, Lisbon, Conn., on September 12th, 1852.

At an early age Mr. Preston showed a liking for mechanics, and began his career with the Greeneville Mills at Norwich, Conn., working as a millwright apprentice. While thus engaged he took up the study of architecture, later completing a course at the Northwestern University, in Chicago, Ill.

During his career, Mr. Preston designed and supervised the building of many of the larger private and public buildings, besides some of the most important mills, in the New England and Middle States.

* Memoir prepared by Charles E. Elwell, M. Am. Soc. C. E.

Mr. Preston was not only a giant in stature, but a big man in every sense of the word. He was an optimist of the most pronounced type and, being blessed with a kind and sympathetic nature, won a host of admiring friends who will miss the hearty greeting which was familiar to all who knew him.

Besides being a member of many fraternities, he belonged to the Putnam Phalanx (a military order) and was a Thirty-second Degree Mason. He was also a member of the American Association of Architectural Engineers.

Mr. Preston had been working unusually hard, and was suffering from nervous exhaustion when he contracted the grippe; this was followed by inflammatory rheumatism, making a combination which even his strong constitution could not withstand, and he died at his home in Norwich, Conn., on April 20th, 1916, after an illness of three weeks.

He is survived by his wife and one son, Charles H. Preston, Jr., M. Am. Soc. C. E., who is a prominent civil engineer of Waterbury, Conn.

Mr. Preston was elected a Member of the American Society of Civil Engineers on October 5th, 1909.

JAMES VINCENT ROCKWELL, M. Am. Soc. C. E.*

Died May 24th, 1916.

James Vincent Rockwell, son of the late Col. James Vincent Rockwell, U. S. A., and Eckley West Rockwell, was born in Princeton, Ind., on September 22d, 1877. He spent his boyhood at the various army posts to which his father was assigned, and, like most sons of officers, could hardly be said to have had a home in the ordinary sense of the word, as applied to a definite locality. He was prepared for college at the Troy Academy, Troy, N. Y., and on his completion of the course in 1894, he entered Rensselaer Polytechnic Institute, from which he was graduated, in 1898, with the degree of Civil Engineer. In his preparatory work, as well as at Rensselaer, he stood first in his class.

Born in the service, and reared under the influence of service conditions, Mr. Rockwell found it impossible to deny the call in his blood when war with Spain broke out, in the spring of his graduating year. He enlisted as a private of volunteers on May 2d, 1898, deliberately sacrificing, as he then thought, the $3\frac{1}{2}$ years of college work and his future professional career as an engineer. On July 1st, 1898, Mr. Rockwell was discharged from the service with the volunteer troops,

* Memoir prepared by Leonard M. Cox, M. Am. Soc. C. E.

in order to accept an appointment as Assistant Engineer in the Navy, with the rank of Ensign, and took the oath of office under this appointment on July 2d, 1898. He was permitted to return to Rensselaer Polytechnic Institute for graduation with his class, of which he was President, and was distinguished as honor man by having his diploma held until all the others had been delivered. A number of his class had enlisted for the war, and could not be present at Commencement. The Board of Trustees delivered the diplomas of the absentees to Mr. Rockwell, with the statement that they knew of none more worthy to receive them.

Mr. Rockwell served at the Navy Yard, New York, and the Navy Yard, Norfolk, Va., during the summer and fall of 1898, and was honorably discharged from the Naval Service in February, 1899. He then accepted a position as Assistant Engineer with the Chicago and Northwestern Railroad, and continued in the service of that Company until July, 1903, rising steadily in the ranks of its Engineering Staff, and enjoying the esteem of his superiors.

The first competitive examination for commission as Assistant Civil Engineer, United States Navy, under the law authorizing the grade, was held at the Navy Yard, New York, in June, 1903. Mr. Rockwell's Navy Yard service during the Spanish War had attracted the attention of Rear-Admiral Endicott, U. S. N., Past-President, Am. Soc. C. E., at that time Chief of the Bureau of Yards and Docks, and it was on the suggestion of that officer that he entered this examination as one of the large number of applicants. The ordeal was most severe and consumed the better part of two weeks, covering practically the entire scope of the standard technical course, as well as practical design and construction of the types of structure with which the maritime engineer has to do. Mr. Rockwell stood first in this examination and was commissioned Assistant Civil Engineer, U. S. N., with the rank of Lieutenant (Junior Grade), on June 27th, 1903. His first duty was at the Navy Yard, Boston, Mass., where he was stationed from July 27th to September 3d, 1903.

From September 8th, 1903, to October 28th, 1904, he was at the Naval Academy, Annapolis, Md., where he served as Resident Engineer on the construction of the new Academy buildings, and as Instructor in Mathematics and Physics. From October 29th, 1904, to July 24th, 1906, he was on duty at the Naval Station, San Juan, Porto Rico, where he was married in July, 1906, to Miss Isabel Romero. From August 15th, 1906, to July 25th, 1909, he was stationed at the Mare Island Navy Yard, as Senior Assistant to the Public Works Officer, Civil Engineer H. H. Rousseau, U. S. N., M. Am. Soc. C. E., and on the appointment of that officer as Chief of the Bureau of Yards and Docks, Mr. Rockwell was left in charge for one year, an unusual mark of confidence in an officer of his age and length of service.

From August 2d, 1909, to January 25th, 1910, he was on duty at the works of the General Electric Company, Schenectady, N. Y., inspecting electrical equipment for use by the Government. From February 1st, 1910, to March 23d, 1911, he was stationed at the Navy Yard, New York, as Senior Assistant to the Public Works Officer. From March 28th, 1911, to January 20th, 1913, he was on duty at the Navy Yard, Charleston, S. C., as Public Works Officer of the station. During this duty, he designed the concrete wharf and sea-wall which has recently been completed, a structure supported on pile-founded piers, built within a steel cylindrical coffer-dam, and involving difficult engineering problems. From January 25th, 1913, to April 20th, 1915, he was on duty at the Bureau of Yards and Docks, Washington, D. C., where he had charge of requisitions and certain of the contract work.

From April 30th to July 15th, 1915, Mr. Rockwell served as Senior Assistant to the Public Works Officer, Navy Yard, New York, and from July 21st, 1915, to May 24th, 1916, he was on duty at the United States Aeronautic Station, Pensacola, Fla. Upon reporting he found himself in the position of Planning Superintendent for the entire station, but despite the arduous duties involved thereby, he formed the conviction that all officers on duty at the Navy's only flying station should qualify as pilots, and, acting on this conviction, he immediately applied for flying work. He had completed the course of instruction and on May 24th, 1916, was undergoing one of the prescribed final tests, when the accident which caused his death occurred.

Mr. Rockwell was an able officer, a skilled engineer, and a gentleman. Somewhat reserved by nature, he nevertheless possessed qualities which endeared him to his friends. He was a man of excellent judgment and strong convictions which he never hesitated to express. He had quite a sense of humor and a quaint philosophy of life which made it impossible for him, or for those associated with him, to magnify the difficulties of any task or any problem. Perhaps his views regarding aviation duty best illustrate the man:

"Don't worry," he said in his personal correspondence, "I have passed the reckless age; I am not going into this for glory. I feel that shore-going staff officers should prepare themselves with a view to relieving line officers from shore duty in time of war—they will be needed at sea. Besides, I have an idea that my Commandant would like to see all of his officers qualify."

True to his service training, his thoughts were first of his duty, as he saw it. Civil Engineer Rockwell was not a man to take unnecessary chances—he did not want to die, but if death had to come to him, he would have wished it to be "in the line of duty." Surely those who have sacrificed themselves in developing the air branch of the

service deserve a place in the memory of their fellow-countrymen with the hero who falls in battle.

He is survived by his wife and three young children; his mother, Mrs. James Rockwell, of Washington, D. C.; a brother, Charles K. Rockwell, late Captain, Corps of Engineers, U. S. A.; and a sister, Miss Helen Rockwell.

Mr. Rockwell was elected a Junior of the American Society of Civil Engineers on April 3d, 1900; an Associate Member on February 4th, 1903, and a Member on November 5th, 1907.

HENRY ROHWER, M. Am. Soc. C. E.*

Died May 4th, 1916.

Henry Rohwer, the son of Henry and Margaret Rohwer, was born on October 17th, 1847, on his father's estate near Rensburg, Holstein, Germany. This estate had belonged to the family for several centuries, the house in which Mr. Rohwer was born being some 200 years old at the time of his birth. He attended the provincial schools, and, later, Dr. Jessen's Polytechnic Institute, at Hamburg, from which he was graduated at the head of his class in 1865, receiving as a Government Prize, a position as Civil Engineer on the East Holstein Railway. On resigning this position to take up further studies at the Royal Polytechnic School, at Hanover, his Chief Engineer wrote:

"Mr. Henry Rohwer has been engaged as Civil Engineer on the East Holstein Railway, in the field, and in the office. All work entrusted to his supervision has been executed by him diligently and carefully. Mr. Rohwer is a man of unusual attainments and of a most attractive personality, an able leader and governor of men."

At the Royal Polytechnic School, Mr. Rohwer took, in addition to the regular civil engineering work, a course in Architecture, and special studies in the general principles of machinery. He stood again at the head of his class when he was graduated, with the degree of Civil Engineer, in 1869.

Broken in health from over study, Mr. Rohwer's physicians ordered a sea voyage, suggesting a trip to South America, but he decided to come to the United States. He went directly to Omaha, where he found employment with the Burlington and Missouri River Railroad in Nebraska, successively as Topographer, Engineer in charge of location and construction, Resident Engineer of that road and Acting Chief Engineer of the Omaha and Southwestern Railroad. He did his work so well that when the Chief Engineer of the Burling-

* Memoir prepared by W. S. Dawley and John Lyle Harrington, Members, Am. Soc. C. E.

ton and Missouri Railroad, Col. Thomas L. Doane, resigned, in 1876, to accept the position of Consulting Engineer of the Hoosac Tunnel, he recommended that Mr. Rohwer be named his successor. This recommendation was approved, and Mr. Rohwer was offered the position. He decided, however, to do private work, and opened an office in Omaha for general practice as a Civil Engineer. During this early connection with the Burlington, one of Mr. Rohwer's advanced parties was massacred, their instruments buried, and their property appropriated by the Sioux Indians. He himself was twice taken by the Indians, but escaped injury through the good offices of the interpreters.

In 1877, engineering work being slack, Mr. Rohwer was one of fourteen candidates for the position of City Engineer of Omaha. He was especially recommended and vouched for by such men as Messrs. Robert R. Livingston, Surveyor-General, William Cleburn, Division Engineer, E. Lane, Engineer and Superintendent of the Building and Bridges Department of the Union Pacific Railroad Company, and the Hon. A. S. Paddock, United States Senator. He was selected and appointed by Mayor-elect, Col. R. H. Wilbur, and, two years later, was re-appointed by Mayor Chase.

While City Engineer, Mr. Rohwer resurveyed and monumented much of the city; established street grades; made a topographical map of the city; planned a sewer system and began its construction; designed water-works; in short, did everything pertaining to the Engineering Department of a young and growing community.

In 1881, Mr. Rohwer again took up railroad work, and was given charge of the location and construction of the first 50 miles of the Oregon Short Line, from Granger, Wyo., west. Before the completion of this 50 miles, he was assigned to the Portneuf River Canyon work and the construction of the line across the Bannock and Shoshone Indian Reservations. As Resident Engineer, he located the line across Snake River at "American Falls", made the triangulation, and took the necessary levels, overcoming unusual difficulties.

In 1883 he was selected by the Chief Engineer, the late Jacob Blickensderfer, M. Am. Soc. C. E., to act as Resident Engineer of the Hodges Pass Tunnel. This tunnel pierces the Uintah Range of the Wasatch Mountains, is 1 532 ft. in length, and was very difficult to construct on account of the many kinds of material and large volume of water encountered, eight separate veins of coal, with various clays, sands, and rock, being found. The tunnel was lined throughout with California redwood, and was extended on each end by snowsheds of the same material to a total length of ½ mile. The plans were well made, the work was well and carefully done, no lives were lost, and many compliments were paid to the engineer and contractor. On the completion of this tunnel in 1884, Mr. Rohwer, against the wish of his Chief Engineer, decided to resign and again

take up private practice. He returned to Omaha where he became interested in the making of brick, designing and patenting a "continuous brick kiln" which has special merit and gives much satisfaction where fuel is expensive. He constructed a number of these kilns throughout the United States.

In 1885, Mr. Rohwer again returned to railroad work and, under Mr. S. H. H. Clark, President of the Missouri Pacific Railroad, located and built the Omaha Belt Railway and the Missouri Pacific Extension to Lincoln, Nebr. In 1887 he was made Engineer in Charge of Maintenance of the Missouri Pacific Railway and its branches, which position he held until March 1st, 1901, when he was advanced to the position of Chief Engineer of the Missouri Pacific Railway and the St. Louis, Iron Mountain and Southern Railway, Leased and Operated Lines. The following is a part of the work done while Mr. Rohwer was Chief Engineer of these lines: Plans and estimates for revision of alignment and reduction of gradients on 900 miles of road, this work being completed as planned on some 550 miles; surveys for some 1 100 miles of new line, of which about 700 miles were built. These new lines include: The Memphis, Helena and Louisiana Railway, 230 miles in length, with its two large draw-bridges (440 ft. and 370 ft.) across the Arkansas and White Rivers; the Eldorado-Bastrop Railway, 44 miles in length, with the Ouchita Draw and its 2 miles of trestle approach; and the White River Railway, 240 miles in length, through the Ozarks of Missouri and Arkansas, costing more than $8 000 000. This line, for most of its length, was of heavy construction, necessitating five tunnels, totaling 2 miles in length, and many steel bridges and viaducts, the latter often reaching a height of 100 ft. or more. This is a road of great scenic beauty.

Mr. Rohwer represented his Company on the Board of Engineers for the Thebes Bridge, and acted as Chairman of that Board. He was at the same time a member of the Board of Chief Engineers for the Kansas City New Union Depot and Terminals.

After 1906 he maintained a consulting engineer's office in St. Louis, devoting his time to consulting and expert service, making reports on railroads, water-works, power-plants, etc. He acted as Consulting Engineer for investors, financial institutions, and municipalities. In the latter capacity he reported on the location and cost of the municipal "Free Bridge," and his report, published by the City, decided the location of that bridge.

Mr. Rohwer was an early advocate of good roads. His address at the first Good Roads Convention of the State of Missouri, held at Sedalia, in January, 1893, was published in full in its proceedings, and contained the strongest arguments advanced. He was at that time called by his friends "The Father of Good Roads."

Mr. Rohwer was a Charter Member of the American Railway Engineering Association; a Member of the Engineers' Club of St. Louis; a Member of the Society of German Engineers, of Berlin, Germany; and a Charter Member of the Fraternity "Hannovera", founded in 1866, of Hanover, Germany. He served as a member of the Roadway Committee of the American Railway Engineering Association, and was active in the St. Louis Club.

He was always a hard worker, and his associates recognized his superior ability for carrying out those undertakings which required continuous and careful attention as well as unusual technical attainments. One contractor writes:

"As a contractor, I had the good fortune to work under Mr. Henry Rohwer during the greater part of the time that he was Chief Engineer of the Missouri Pacific and Iron Mountain Railroads. He was an honorable man, slow to anger, scrupulously just, and always ready to commend work well done. The majority of contractors were always glad to do work under him, knowing they would receive fair treatment at his hands, consequently, construction work under his management was prosecuted promptly and to the satisfaction of all parties concerned."

Aside from his eminence as an engineer, Mr. Rohwer was a good man and greatly devoted to his home and family. He was married on October 8th, 1873, to Anna Sievers, of Omaha, Nebr., who survives him, with three of their five children, Oscar H. D., Henry G. A., and Anna Louise.

His only recreation was taken with his family. He kept them near him whenever possible. He had them for a year at his camp when constructing the Hodges Pass Tunnel. At that time there were no white settlers in Southwestern Wyoming, and the Indians of the reservations crossed were not at all times friendly. While an officer of the Missouri Pacific Railway, it was his custom to take one or more of his family with him when making trips down the line.

At the funeral services, his pastor spoke of him as the most modest of men. His daughter writes of him as follows:

"The devotion of Mr. Rohwer to his family was exemplary, and his life was one beautiful harmony. In the gentleness so characteristic of himself, despite weakness, pain, and growing apprehension, the only greeting ever received was a smile. His death has its own peculiar pathos, and he met it, as he met all else in life, with a resolute determination. There was no outward expression of inward lassitude, nor was there a portrayal of weakness or of waning fortitude. His was a long heroic uncomplaining struggle, and every obligation on the part of his family was lovingly met. Sclerosis of the arteries, affecting the heart, caused undescribable suffering, both mental and physical. He bade the members of his family farewell the day before his death, which occurred on the afternoon of May 4th, 1916. The remembrance of his personal qualities and the beauty and rarity of

his spirit, together with the love and esteem in which he was held by all who knew him, to some degree, temper the grief of those who mourn him."

Mr. Rohwer was of a quiet, unobtrusive disposition, and did not seek the world's plaudits; but he fought a good fight, lived an honorable and useful life, and earned the world's esteem.

Mr. Rohwer was elected a Member of the American Society of Civil Engineers on April 1st, 1903.

GEORGE WASHINGTON VAUGHN, M. Am. Soc. C. E.*

Died February 3d, 1916.

George Washington Vaughn was born at Perry, N. Y., on November 24th, 1829.

He began his engineering career about 1854, when he made the plans and surveys for bringing from the mountains of California what was perhaps the first water supply for the purpose of hydraulic mining. This work was followed by plans for a series of dams in various California streams. He then took up Government land surveying in the Northwest.

In the summer of 1857, Mr. Vaughn was engaged as Levelman on the location of the Winona and St. Peter Railroad, the first railroad in Minnesota, and served as Division Engineer on the construction of that road until April, 1858.

On the completion of this work, he accepted a very lucrative offer to take charge of the construction of levees on the Mississippi River in Arkansas. While he was engaged on this work, the Civil War broke out, and he enlisted in the Federal Army and was assigned the management of the collection of rentals of business and public buildings in Memphis, turning the collections over to the War Department.

After the war, Major Vaughn, with a few others, decided to locate a town in the State of Kansas, and accordingly he surveyed and laid out the Town of Ellsworth, named for Col. Ellsworth, one of the first to fall in the Civil War. It is now the seat of Ellsworth County. The first site chosen for the town, being too near the river, was threatened with floods. The town was moved, therefore, and Major Vaughn's engineering ability was called into play to devise means of moving the houses back to the new site, which he had already surveyed and which is the location of the present city.

In the early days of Ellsworth, Major Vaughn and others were compelled to become vigilantes in order to rid the community of gamblers, murderers, and cut-throats by the primitive method of

* Memoir prepared by the Secretary from information furnished by J. M. Willard, Esq., and on file at the Society House.

hanging, and after order was restored, respectable people were encouraged to settle there.

Major Vaughn decided, however, that Leavenworth was more desirable as a residence, on account of the better educational advantages open to his children, and in 1869, he purchased a home in that city, which he continued to occupy until his death.

He then took up railroad engineering, and from April to August, 1869, served as Division Engineer on the Leavenworth, Atchison and Northwestern Railway, now part of the Missouri Pacific System. In 1870 and 1871, he was engaged as Chief Engineer of the Kansas Central Railway, a narrow-gauge road running west from Leavenworth. On the completion of this road, Major Vaughn served until 1874 as Chief Engineer of the Wyandotte, Kansas City and Northwestern Railway (now also a part of the Missouri Pacific System) running from Kansas City to Lexington, Mo. In 1875 and 1876 he was Superintendent of the same line, and in 1878 he was again appointed Chief Engineer of the Kansas Central Railroad.

In 1879, he was engaged as Resident Engineer on the Denver and Rio Grande Railroad, in charge of the location and construction of two lines over the Continental Divide, one at Ten-Mile Pass and the other at Marshall Pass.

In 1880, Major Vaughn went to Mexico as Chief Engineer of the Northern Division of the Mexican Central Railway and of the Mexican National Railway north of the City of Mexico where he made his headquarters, completing the line to San Miguel and a branch to Morelia.

In 1886 and to April, 1887, he was Chief Engineer of the Leavenworth, Northern and Southern Railway, now a part of the Santa Fé System, and from April, 1887, to December, 1890, he was Assistant Chief Engineer of the Chicago, Santa Fé and California Railway, a line connecting Kansas City with Chicago, Ill.

On the completion of this line Major Vaughn was made Consulting Engineer of the Atchison, Topeka and Santa Fé Railroad. He served as Vice-President and Chief Engineer of the Santa Fé, Prescott and Phœnix Railway, with headquarters at Prescott, Ariz., from 1892 to 1895, but he did not like the routine of the office and resigned to return to his home in Leavenworth, Kans.

In 1897, he was called to Chicago to take charge of the work known as the 16th and Clark Streets Track Elevation. This comprised the elevation of the tracks of nine railroads operating 1 000 trains per day, and was accomplished without the stoppage of traffic during construction. It was considered one of the greatest engineering achievements of its kind in the world.

On the completion of this work in 1899, Major Vaughn was appointed Engineer in Charge of the Joint Track Elevation for the

Illinois Central, the Atchison, Topeka and Santa Fé, and the Chicago and Alton roads, to extend the track elevation from 18th Street west 3 miles, at a cost of $1 000 000 per mile. This work was completed in 1905. In 1906 he was called to take charge of the track elevation of the Atchison, Topeka and Santa Fé Railway through the City of Joliet, Ill.

On completing this work, in 1911, Major Vaughn felt that, after his long career of sixty years of engineering work, he deserved retirement, and he returned to his home in Leavenworth to enjoy the quiet of his remaining years.

His life of sturdy honesty and high principles, together with his marked ability, made a character such as is not often met in these days, and led to an impregnable position in the Engineering Profession.

Major Vaughn was elected a Member of the American Society of Civil Engineers on June 3d, 1891.

JAMES KNAPP WILKES, M. Am. Soc. C. E.*

Died January 8th, 1916.

James Knapp Wilkes was born in Danbury, Conn., on August 21st, 1859. He was the only son of Matthew and Henrietta Knapp Wilkes, whose ancestors settled in Connecticut in the Seventeenth Century.

After he was graduated from the Danbury High School in 1876, he took up the study of scientific and engineering subjects under private tutors for two years, and in 1880 was graduated from the State Normal College at Albany, N. Y. During the same year Mr. Wilkes entered the office of Mr. D. G. Penfield, of Danbury, Conn., and was engaged in general engineering work in that vicinity, including the construction of the New York and New England Railroad between Danbury, Conn., and Hopewell Junction, N. Y.

In 1884 he opened an engineering office, and engaged in private work; he also performed all the engineering work required for the Borough of Danbury.

In 1887 Danbury became a city, and, in addition to his private duties, Mr. Wilkes was appointed City Engineer, having charge of all the municipal work, including regulating, grading, and paving streets, the construction of sewers, and the extension of the water supply, together with the distribution system and the enlargement of the dams and reservoirs. In addition to his duties for the City of Danbury, he also constructed and designed a dam and pipe line near Bethel, Conn., besides being engaged as expert on legal questions arising from the development of water power in that vicinity.

In 1890 Mr. Wilkes went to New Rochelle, N. Y., as Assistant Engineer in charge of the construction of sewers which had been designed

* Memoir prepared by C. W. S. Wilson, M. Am. Soc. C. E.

and were being constructed under the direction of the late Horace Crosby, M. Am. Soc. C. E.

In 1891 he was again called to Danbury to take up the work of City Engineer, and he held that office until 1893, when he was appointed Chief Engineer of the Sewerage Commission of New Rochelle, N. Y., which position he held for 6 years, having charge of the design and extensions of the sewers and storm-water drains, as well as a sewage purification works, by chemical precipitation, for taking care of the sewage from the westerly half of the city. Owing to the rapidly increasing growth of the city, it became necessary to remove the original eastern outlet, in order to prevent the pollution of the shores and bathing beaches. Mr. Wilkes solved the problem by carrying the sewage through a tunnel driven under Hudson Park and a submerged pipe under the harbor, 3 000 ft. into Long Island Sound. In addition to this sewerage construction, he also had charge of the maintenance and repairs of the sewers and drains throughout the city.

In 1899 Mr. Wilkes was engaged by the Metropolitan Street Railroad in the construction of a double-track electric system through 42d Street, New York City.

In 1900 he was employed by The Hoffman Engineering and Contracting Company, as Engineer in the construction of the foundations for the new cadet quarters at the United States Naval Academy, Annapolis, Md.

In 1901 he was Superintendent for Mr. W. A. Engeman, on the construction of a railroad from the Connecticut River to Benvenue granite quarries and the erection of cableways at quarries near Middletown, Conn.

In 1902 Mr. Wilkes was appointed City Engineer of New Rochelle, N. Y., which position he held until 1912, having charge of all engineering matters pertaining to the city, the work consisting principally in the improving and paving of streets, extending sewers, and building a 30-in. inverted siphon sewer under Echo Bay. In 1912 he resigned as City Engineer and formed the Wilkes-Casey Engineering and Contracting Company, of which he was President, carrying on general construction work for municipal and private operation, the Company's work being confined principally to the States of New York and Connecticut.

Mr. Wilkes was taken sick on January 1st, 1916, and died of pneumonia at his home in New Rochelle on January 8th, 1916. In 1885 he was married to Capitola Baker, of Patterson, N. Y., who, with one daughter, survives him.

Mr. Wilkes was elected an Associate Member of the American Society of Civil Engineers on June 3d, 1891, and a Member on April 3d, 1906. He was also a Charter Member of the Connecticut Society of Civil Engineers.

ARTHUR FRANCIS WROTNOWSKI, M. Am. Soc. C. E.*

Died October 28th, 1911.

Arthur Francis Wrotnowski, the son of Stanislaus Wrotnowski and Catharine Ozibulska Wrotnowski, was born on October 14th, 1843, at Clermont, France, where his father was then a beet sugar manufacturer. When he was eleven years old, he came to the United States with his parents who settled at Baton Rouge, La., where his father had a cane-sugar mill.

During the Civil War (1862) he enlisted in the Federal Army and was made Lieutenant-Colonel of an Engineering Corps stationed in Texas during the latter years of the war.

In January, 1868, Col. Wrotnowski was married to Miss Josephine Rachel Thomas, of Philadelphia, Pa.

During the construction of the jetties at the mouth of the Mississippi River, he served on the Board of State Engineers of Louisiana and, in 1876, he was appointed Chief State Engineer of that Board. He was also Supervising Architect of the Custom House at New Orleans, La., which was being remodeled, from 1878 to 1881.

During 1882-83, he was in charge of the harbor works at Vera Cruz, Mexico, under a French company which discontinued the work there in 1883.

Mrs. Wrotnowski died in May, 1883, and in the following year, Col. Wrotnowski having invested heavily in Florida, made his home there, in order to look after his investments. He founded the Town of Clermont, called after his birthplace in France.

In February, 1885, he was married to Miss Angie Bladen, of Philadelphia, Pa.

In 1887-88 he was connected with the East Coast Canal Company of Florida and, in 1889, went to Tampico, Mexico, as Resident Engineer in charge of the construction of the jetties at the mouth of the Panuco River, which were being built by the Mexican Central Railway and of which the late E. L. Corthell, President, Am. Soc. C. E., was Consulting Engineer in charge. These works were completed in 1892, and Col. Wrotnowski then opened an engineering office in New Orleans, La.

In 1895 he had charge, for a few months, of the harbor works of Vera Cruz, Mexico, then being built by Sir Weetman Pearson, now Lord Cowdrey.

About 1897, he removed to the western coast of Mexico and settled at Guaymas and Hermosillo, Sonora. He constructed a number of buildings in these two cities, among which were the State Penitentiary, markets, bank, etc., etc.

* Memoir prepared by the Secretary from information on file at the Society House.

Col. Wrotnowski's declining years were marred by prolonged ill health, and he only survived his second wife by about 6 months. He died on October 28th, 1911, in Nogales, Ariz., where he had gone for his health, and is buried there. He is survived by one daughter by his first marriage, Mrs. C. F. de Ganahl, of New York City, and by two daughters and a son, by his second marriage, Mrs. Van Archibald Smelker and Mrs. William Wells Griffith, both of Nogales, Ariz., and Arthur Corthell Wrotnowski, of San Diego, Cal.

Col. Wrotnowski was elected a Member of the American Society of Civil Engineers on July 12th, 1877.

GEORGE LENOX CRAWFORD, Assoc. M. Am. Soc. C. E. *

Died February 3d, 1916.

George Lenox Crawford was born near Napoleon, Henry County, Ohio, on June 23d, 1864. He attended the public schools, and, during vacations, assisted his father in drainage engineering, etc., which fact probably influenced his choice of a profession.

In June, 1886, Mr. Crawford entered the service of the Union Pacific Railroad as Chainman and Rodman, and, from that time until September, 1890, he was employed as Rodman, Transitman, Assistant Engineer, and Field Engineer, with the Tremont, Elkhorn and Missouri Valley Railroad, the St. Louis and San Francisco Railway, the New Orleans and Northwestern Railway, and the Springfield (Mo.) Electric Street Railway, respectively.

In September, 1890, he began the work with which he was identified during the latter part of his professional life, namely, coal-mining engineering, as Principal Assistant to the Chief Engineer of the Kansas and Texas Coal Company, at St. Louis, Mo. In this capacity, Mr. Crawford had charge of surveys and of the design and installation of coal-mining and coal-handling plants.

From September, 1892, to 1894, he was engaged in private practice as Consulting Engineer on mining and irrigation work at Springfield, Mo., and also at Gunnison, Colo.

In November, 1894, Mr. Crawford returned to railroad engineering as Engineer of the Bridge and Building Department of the Colorado and Southern Railway, at Pueblo, Colo., which position he retained until November, 1895, when he again took up private practice.

From November, 1897, to July, 1898, Mr. Crawford, as Chief Engineer, made surveys, plans, and estimates for a double-track, electric and steam railroad for the Kansas City-Leavenworth Electric Railway,

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* Memoir prepared by the Secretary from material furnished by A. L. Fellows, M. Am. Soc. C. E., supplemented by data on file at the Society House.

Power and Mining Company of Leavenworth, Kans., but the project was never carried out. In August, 1898, he went to Wyoming as Assistant Engineer on the construction of the new steel main line of the Union Pacific Railroad from Granger to Piedmont, and from January to June, 1899, he served as Transitman on location and in charge of the construction of the tunnel and bridges on the La Veta Cut-Off of the Denver and Rio Grande Railroad.

In June, 1899, Mr. Crawford returned to the practice of coal-mining engineering, in which, except during his term as City Engineer of Grand Junction, Colo., he continued until his death. From June, 1899, to January, 1905, he was Chief Engineer of the Northern Coal and Coke Company at Denver, Colo., in charge of mine surveys, the design and construction of coal-mining plants, and in making estimates and reports on coal properties, etc. From that position, he went, as Chief Engineer, to the Rocky Mountain Fuel Company, and, in May, 1907, he was appointed General Superintendent and Chief Engineer of the Tam O'Shanter Montezuma Mines and Development Company. For this latter Company, he designed a hydro-electric power plant and an aerial tramway and terminals, and had charge of the construction of a 50-ton concentrating mill.

In February, 1908, Mr. Crawford again took up consulting work, which he continued until April, 1909, when he was elected City Engineer of Grand Junction, Colo., which office he held until 1913. While in this position he designed and constructed sewers, pavements, and a water-supply line for that city. In 1913, he again returned to private practice as a Consulting Engineer with headquarters at Denver, Colo., until 1914, when he was appointed General Superintendent of The Pike's Peak Fuel Company, at Colorado Springs, Colo., which position he held until his death, on February 3d, 1916, from cerebrospinal meningitis following an attack of pneumonia.

From his boyhood, Mr. Crawford had been a hard worker. Owing to the fact that his father died while he was still young, he had to forego any college or technical training except that which he obtained through his own efforts and studies; nevertheless, he was well educated in the best sense of the word.

He was a man of high moral character, modest and unassuming, but efficient and thorough, and a true friend once his friendship was won. His honor was his first and highest concern.

He was a member of the Plymouth Congregational Church, and a Mason, having been a member of Union Lodge No. 7, of Denver, Colo.

The following resolutions on Mr. Crawford's death, which were adopted by the Colorado Association of Members of the American Society of Civil Engineers, of which he was a member, were presented before the meeting of that Association on February 12th, 1916:

"*Resolved:* That we, the members of the Colorado Association of Members of the American Society of Civil Engineers, deeply deplore our loss, recognizing at the same time in his removal a loss not only to ourselves, but to the community at large; and, further,

"*Resolved:* That this statement and these resolutions be spread upon the records of this organization and that a copy thereof be sent to his family with an expression of our most sincere sympathy."

Mr. Crawford was elected an Associate Member of the American Society of Civil Engineers on September 3d, 1912.

PAPERS IN THIS NUMBER

ADDRESS AT THE ANNUAL CONVENTION, IN PITTSBURGH, PA., June 27th, 1916. CLEMENS HERSCHEL.

"TUNNEL WORK ON SECTIONS 8, 9, 10, and 11, BROADWAY-LEXINGTON AVENUE SUBWAY, NEW YORK CITY." ISRAEL V. WERBIN. (To be presented Sept. 20th, 1916.)

"EARTH PRESSURES: A PRACTICAL COMPARISON OF THEORIES AND EXPERIMENTS." L. D. CORNISH.

"UNDERPINNING TRINITY VESTRY BUILDING FOR SUBWAY CONSTRUCTION." H. DE B. PARSONS. (To be presented Oct. 4th, 1916.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

PAPERS IN THIS NUMBER

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 7

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September, 1916

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLII—No. 7

SEPTEMBER, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1916

American Society of Civil Engineers

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ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, Charles S. Churchill, Leonard Metcalf, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus.

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The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

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Vol. XLII. SEPTEMBER, 1916. No. 7.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

September 6th, 1916.—The meeting was called to order at 8.30 P. M.; T. Kennard Thomson, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 85 members and 8 guests.

The minutes of the meetings of May 17th, May 24th, June 7th, and of the Annual Convention (June 27th, 1916), were approved as printed in *Proceedings* for August, 1916.

A paper by J. C. Allison, Assoc. M. Am. Soc. C. E., entitled "Control of the Colorado River as Related to the Protection of Imperial Valley" was presented by the Secretary who also read communications on the subject from Messrs. A. L. Sonderegger and J. A. Ockerson.

The Secretary announced the following deaths:

DON JUAN WHITTEMORE (*Past-President*), of Milwaukee, Wis., elected Member, July 10th, 1872; Honorary Member, January 6th, 1911; died July 16th, 1916.

THOMAS APPLETON, of Gardiner, Me., elected Member, April 4th, 1883; died August 3d, 1916.

Miguel de Teive e Argollo, of London, England, elected Member, October 2d, 1895; died May 14th, 1916.

Edward Canfield, of Middletown, N. Y., elected Member, December 3d, 1879; died August 18th, 1916.

Henry Arthur Hall, of Sumner, Wash., elected Member, May 7th, 1902; died June 6th, 1916.

Arthur Hider, of Greenville, Miss., elected Member, September 7th, 1881; date of death unknown.

Joseph Otis Osgood, of New York City, elected Junior, May 3d, 1876; Member, March 5th, 1879; died June 28th, 1916.

William Rodney Patterson, of Chicago, Ill., elected Member, May 4th, 1909; died July 20th, 1916.

Ernest Frederick Tabor, of St. Ignatius, Mont., elected Member, May 1st, 1907; died August 20th, 1916.

Frank Joseph Conlon, of Brooklyn, N. Y., elected Associate Member, March 2d, 1915; died June 28th, 1916.

Stanley Hastings McMullen, of Jeffersonville, Ind., elected Associate Member, November 3d, 1915; died July 12th, 1916.

Roy Karl Schlafly, of Columbus, Ohio, elected Associate Member, September 3d, 1913; date of death unknown.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

September 12th, 1916.—The Board met at 10.30 P. M.; Vice-President Craven in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bush, Davies, Endicott, Harwood, and Tuttle.

Ballots for Membership were canvassed, resulting in the election of 19 Members, 50 Associate Members, 5 Associates, and 19 Juniors, and the transfer of 25 Juniors to the grade of Associate Member.

Nine Associate Members were transferred to the grade of Member.

A Report from the Membership Committee was received and acted upon.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

October 4th, 1916.—8.30 P. M.—This will be a regular business meeting. A paper by H. de B. Parsons, M. Am. Soc. C. E., entitled "Underpinning Trinity Vestry Building for Subway Construction", will be presented for discussion.

This paper was printed in *Proceedings* for August, 1916.

October 18th, 1916.—8.30 P. M.—At this meeting a paper by J. B. Lippincott, M. Am. Soc. C. E., entitled "A Method of Determining a Reasonable Service Rate for Municipally Owned Public Utilities", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

November 1st, 1916.—8.30 P. M.—A regular business meeting will be held, and a paper by F. H. Peters, Assoc. M. Am. Soc. C. E., entitled "A Complete Method for the Classification of Irrigable Lands", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which

is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings*, and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings*.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

President, H. L. Haehl; Secretary, E. T. Thurston, 57 Post Street, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary.

(Abstract of Minutes of Meeting)

August 15th, 1916.—The meeting was called to order at the Palace Hotel; President H. L. Haehl in the chair; E. T. Thurston, Secretary; and present, also, 74 members and guests.

The guests of the Association at this meeting were Wilbur J. Watson, M. Am. Soc. C. E., and Mr. Harlan D. Miller, of Cleveland, Ohio, E. E. Howard, M. Am. Soc. C. E., of Kansas City, Mo., and Charles Evan Fowler, M. Am. Soc. C. E., of Seattle, Wash.

The Secretary read a preliminary report of the Committee appointed to consider the suggestions contained in President Haehl's Inaugural Address on "The Growth in Power and Usefulness of the Association". In view of the fact that the proposed amendments to the Constitution of the Society will greatly affect this problem, the Committee recommended that the matter be held in abeyance pending final action on the amendments.

Messrs. Cattell, Duryea, and Couchot, a committee appointed to attend the public hearing before a Board of United States Army Engineers, in the matter of the San Francisco-Oakland Bridge, reported that plans for such a bridge had been submitted by Messrs. Wilbur J. Watson and Harlan D. Miller, and by Mr. Charles Evan Fowler, and as these gentlemen were present at the meeting, suggested that they be called on to speak.

Brief addresses were made by Messrs. Watson, Miller, Howard, and Fowler, and Mr. Fowler showed stereopticon views of bridge structures, illustrating the evolution of bridges and exhibiting interesting details of modern bridge construction.

The entertainment provided by the Committee consisted of a male quartet from the University of California. President Haehl appointed Messrs. Charles Gilman Hyde, F. S. Foote, Jr., and B. A. Etcheverry, as the Entertainment Committee for the October meeting.

A paper on "The Proper Relation of Responsibility and Authority" was presented by Mr. George L. Dillman, but, owing to the lateness of the hour, on motion, duly seconded, discussion thereon was postponed until some future meeting.

Adjourned.

Colorado Association, Organized 1908.

President, Thomas W. Jaycox; Secretary-Treasurer, L. R. Hinman, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniels & Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

President, Paul H. Norcross; Secretary-Treasurer, Thomas P. Branch, Georgia School of Technology, Atlanta, Ga.

The Association holds its meetings at the University Club, Atlanta, Ga. Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

Baltimore Association, Organized 1914.

President, H. D. Bush; Secretary-Treasurer, Charles J. Tilden, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

President, Robert Hoffmann; Secretary-Treasurer, George H. Tinker, Hickox Building, Cleveland, Ohio.

District of Columbia Association, Organized 1916.

President, A. P. Davis; Secretary-Treasurer, John C. Hoyt, U. S. Geological Survey, Washington, D. C.

Illinois Association, Organized 1916.

President, Onward Bates; Secretary-Treasurer, E. N. Layfield, 4251 Vincennes Avenue, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

President, W. B. Gregory; Secretary, E. H. Coleman, 920 Hibernia Building, New Orleans, La.

Northwestern Association, Organized 1914.

President, W. L. Darling; Secretary, Ralph D. Thomas, Minneapolis, Minn.

Philadelphia Association, Organized 1913.

President, Edward B. Temple; Secretary, W. L. Stevenson, 412 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

Portland, Ore., Association, Organized 1913.

President, J. P. Newell; Secretary, J. A. Currey, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1914.

President, J. A. Ockerson; Secretary-Treasurer, Gurdon G. Black, 34 East Grand Avenue, St. Louis, Mo.

The meetings of the Association are held at the Engineers' Club Auditorium. The Annual Meeting is held on the fourth Monday in November. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

San Diego Association, Organized 1915.

President, George Butler; Secretary-Treasurer, J. R. Comly, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

President, A. O. Powell; Secretary-Treasurer, Carl H. Reeves, 4722 Latona Avenue, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Northold Inn, 212 University Street.

(Abstract of Minutes of Meetings)

July 31st, 1916.—The meeting was called to order at 12.15 P. M., at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 16 members and guests.

The minutes of the meeting of June 26th, 1916, were read and approved.

The President announced that he had appointed Messrs. Henry L. Gray, Chairman, T. A. Noble, and Paul P. Whitham, as delegates to the Water Code Conference which was held in Tacoma, Wash., on July 11th-12th, 1916.

Mr. A. Münster, Chairman of the Soils Committee, reported on the work and meetings of that Committee.

In the absence of Mr. Gray, a brief report on the work of the Water Code Conference was presented by Mr. Noble, in which he stated that a Conference Committee of seven had been appointed to compile suggestions received relative to the Water Code and to draw up a bill to be submitted to a general meeting of the Conference to be held in North Yakima in November.

The President called the attention of the meeting to the fact that the Conference Committee was composed of three lawyers, three engineers, and one business man, and that of the three engineers, all of whom were members of the Society, two were also members of the Association.

Mr. Bertram D. Dean, representing the Association on the Creosoted Timbers Committee, presented a progress report of the work of that Committee.

The resignation of Mr. Arthur T. Nelson, as a member of the Association, on account of removal from the city, was read and accepted.

A discussion of the relations between the National Engineering Societies and the Local Associations of their members, which had been set down for this meeting, was opened by Mr. Ernest B. Hussey, and the subject was also discussed by Messrs. Fuller, Noble, Powell, and Reeves.

On motion, duly seconded, it was decided to appoint a committee to report on this subject as discussed and printed on page 317, *et seq.*, of the May, 1916, *Proceedings* of the Society.

Mr. A. D. Butler, Secretary of the Spokane Association, addressed the meeting, referring briefly to the relationship between the various technical associations of Spokane and the National Societies, and also to the proposed Water Code of the State of Washington.

Adjourned.

August 28th, 1916.—The meeting was called to order at 12.15 P. M., at The Northold Inn; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 15 members and guests.

The minutes of the meeting of July 31st, 1916, were read and, after slight correction, approved.

The President announced that, in accordance with the action of the Association at its meeting of July 31st, 1916, he had appointed Messrs. A. H. Fuller, E. B. Hussey, and Joseph Jacobs as a committee to report on the subject-matter covered on page 317 *et seq.*, of the May, 1916, *Proceedings* of the Society, namely, the relations existing between National Engineering Societies and local associations of their members.

On motion, duly seconded, Messrs. H. F. Flynn and P. A. Franklin were appointed as additional members of this Committee.

Mr. C. C. Moore was appointed to fill the vacancy on the Soils Committee caused by the removal of Mr. J. R. West to China.

The question of a change in the place for holding the regular monthly meetings and luncheons was discussed, and the Secretary-Treasurer was instructed to see what other arrangements could be made and to act with President Powell in making a selection.

Mr. Henry L. Gray, Chairman of the Water Code Conference Committee, presented his report in a letter to the President. After discussion by Messrs. Hussey, Powell, Gray, Jacobs, and Dean, on motion, duly seconded, the letter report was accepted and placed on file, and the Committee was instructed to amend the present Water Code Bill to cover the ideas set forth in the Report and the suggestions made by the members who discussed it.

On motion, duly seconded, the question of co-operation with the local architects *in re* a licensing bill to be presented to the next Legislature, was referred to the Legislative Committee.

Adjourned.

Southern California Association, Organized 1914.

President William Mulholland; Secretary, W. K. Barnard, 701 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

(Abstract of Minutes of Meeting)

July 12th, 1916.—The meeting was called to order at the Hotel Clark, at 6.45 P. M.; Vice-President Louis C. Hill in the chair; F. G. Dessery, Temporary Secretary, acting as Secretary.

The minutes of the meetings of the Association, of April 8th, 1916, and of the Board of Directors, of May 12th, 1916, were read and approved.

The Secretary read a letter from F. H. Newell, M. Am. Soc. C. E., addressed to Mr. J. B. Lippincott, relative to a "Federal Water Law". The subject was discussed by Mr. Hill, and it was suggested that a committee be appointed to co-operate in the matter. President Mulholland appointed Messrs. Hill, Hawgood, and Quinton, as such Committee.

A paper by Mr. J. C. Allison, entitled "Control of the Colorado River as Related to the Protection of Imperial Valley", was presented by the author, and the subject was discussed by Messrs. Hill, Binckley, Smith, Olberg, Dennis, and Moody.

Mr. Harold Fisk Holley was admitted as a Member of the Association.

On motion, duly seconded, the following resolution was adopted unanimously:

"*Whereas,* It is the duty of every patriotic engineer to prepare himself to be of the greatest service to his country in time of need; and

"*Whereas,* The Engineering Corps of California is striving to effect this object; therefore be it

"*Resolved,* by the Southern California Association of Members of the American Society of Civil Engineers, that we heartily endorse the purposes of the California Corps of Engineers."

Mr. Binckley, of the Meteorological Committee, reported progress.

On motion, duly seconded, a vote of thanks was given Mr. Allison for his instructive paper.

Adjourned.

Spokane Association, Organized 1914.

President, Ulysses B. Hough; Secretary, A. D. Butler, Spokane, Wash.

Texas Association, Organized 1913.

President, John B. Hawley; Secretary, J. F. Witt, Dallas, Tex.

Utah Association, Organized 1916.

President, E. C. La Rue; Secretary-Treasurer, H. S. Kleinschmidt, 306 Dooley Building, Salt Lake City, Utah.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Steel Columns and Struts

June 28th, 1916.—The meeting was called to order at 12 M., on the Steamer *Sunshine* during the trip down the Monongahela River, at the Annual Convention, Pittsburgh, Pa. Present, George H. Pegram (Chairman), Charles F. Loweth, George F. Swain, and Lewis D. Rights (Secretary). Dr. G. R. Olshausen, of the Bureau of Standards, was also present.

The minutes of the meeting of April 6th, 1916, were approved as written.

For the Committee on Initial Sets, Dr. Olshausen reported progress. Attention was called to the discussion before the Annual Meeting of the American Society for Testing Materials on the relation between yield point, elastic limit, and proportional limit. Dr. Olshausen stated that he had submitted a discussion on these subjects to that Society, and agreed to send copies of his discussion to the members of the committee, together with a report on the same subjects which he had recently made to other departments of the United States Government. The Committee was continued.

Dr. Olshausen reported that the Bureau of Standards had not had an opportunity to make the necessary experiments preliminary to proceeding with the transverse tests.

On motion, duly seconded, the matter of special grades of steel and the question of heat treatment were left open, to be considered in connection with a subsequent programme.

After adjourning at 1 P. M. for luncheon, the meeting was called to order at 2 P. M.

After considerable discussion, on motion, duly seconded, the Chairman and Secretary were ordered to prepare an abstract of all the discussions which have been received on Safe Working Stresses and to submit it to the members of the Committee. Mr. J. R. Worcester will be requested to submit his closing discussion at a subsequent meeting.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten=Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From August 2d to September 5th, 1916)

DONATIONS*

WATER WORKS HANDBOOK

Compiled by Alfred Douglas Flinn and Robert Spurr Weston, Members, Am. Soc. C. E., and Clinton Lathrop Bogert, Assoc. M. Am. Soc. C. E. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 9 + 824 pp. New York, McGraw-Hill Book Company, Inc.; London, Hill Publishing Co., Ltd., 1916. $6.00.

This book gives, the preface states, a usable compilation of information, old and new, on hydraulics and water supplies, for the water-works engineer and superintendent, the designer, constructor, operator, and inspector. The subject-matter, which has been accumulated by the compilers in the course of their practice in the various branches of water-works engineering, is arranged by grouping the contents under the natural topics, each topic being subdivided and its divisions arranged sequentially. All matter not readily classified is arranged under the heading, Miscellany. The user is assumed to be familiar with mathematics, hydraulics, the natural sciences, and water-works construction, operation and maintenance, and to possess ordinary mathematical tables. Instead of rules or formulas, data have been given, in some cases, from which the engineer can make his own determinations in accordance with local conditions, etc. Descriptions of materials, apparatus, equipment, methods, formulas, and business concerns are included, but mention of them, it is stated, does not necessarily imply approval by the compilers. The specifications included have been stripped, it is said, of useless non-technical matter and words, in order that the user may amplify and arrange his own materials in proper form when preparing a contract. The Contents are: Part I, Sources of Water Supply; Part II, Collection of Water; Part III, Transportation and Delivery of Water; Part IV, Distribution of Water; Part V, Character and Treatment of Water; Index.

MOSQUITO CONTROL IN PANAMA:

The Eradication of Malaria and Yellow Fever in Cuba and Panama. By Joseph A. Le Prince and A. J. Orenstein. With an Introduction by L. O. Howard. Cloth, $8\frac{3}{4}$ x $6\frac{1}{4}$ in., illus., 17 + 335 pp. New York and London, G. P. Putnam's Sons, 1916. $2.50.

One of the authors, Mr. Le Prince, was with General Gorgas, as his Chief Assistant, during the health campaign against malaria and yellow fever in Cuba. When General Gorgas was sent to the Canal Zone by the Isthmian Canal Commission, Mr. Le Prince went with him, and this book contains a carefully prepared, detailed record of how both places were cleared of mosquitoes, and consequently of malaria and yellow fever, the study made of their habits, etc., the methods used to eradicate them and protect the people from their bite, the system of inspection installed, etc., etc. The work of these men has been an object lesson for sanitarians all over the world, and has demonstrated, it is stated, that it is possible for the white man to live healthfully in the tropics. This record of their work, therefore, should prove of great practical importance as a guide in future work of the same character, especially in the tropics, as well as of permanent historic value of work already accomplished. The Contents are: Part I, Anti-Malaria Campaign: The Status of Knowledge of Anti-Malaria Work in 1904 and the Previous Campaign in Havana; The Situation on the Isthmus in 1904, Before American Occupation; Meteorological and Topographical Conditions; The Species of Anopheles on the Isthmus; Anopheles Propagation Areas; Harboring Places and Food of Anopheles; Flight and Attraction of Mosquitoes; Attack on Propagation Areas by Filling; By Drainage; By Oiling; By Larvacides; By Natural Enemies; By Clearing Bodies of Water; By Removal of Jungle; Screening and Practical Destruction of Adult Anopheles in Houses; The Results Accomplished by the Anti-Malaria Campaign. Part II, The Yellow Fever Campaign: The Campaign in Havana; The Situation on the Isthmus before Sanitary Work was Started; Geography, Meteorology, etc., and Their Bearing on the Presence of Aëdes Culopus; The First Sanitary Work Done in Panama; The Anti-Yellow Fever Campaign and Its Results; Measures Taken to Keep the Isthmus Free from Yellow Fever; The Value of Yellow Fever Eradication in the Construction of the Panama Canal; Index.

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* Unless otherwise specified, books in this list have been donated by the publishers.

HANDBOOK FOR HIGHWAY ENGINEERS:

Part I, Principles of Design; Part II, Practice of Design and Construction. By Wilson G. Harger, Assoc. M. Am. Soc. C. E., and Edmund A. Bonney. Second Edition, Entirely Revised and Enlarged. Morocco, 7 x $4\frac{1}{4}$ in., illus., 16 + 609 pp. New York, McGraw-Hill Book Company, Inc.; London, Hill Publishing Co., Ltd., 1916. $3.00.

In the preface to the first edition, issued in 1912, and in the secondary title, it is stated that the purpose of this book is to collect, in a compact and convenient form, information ordinarily used in the design and construction of roads warranting an expenditure of from $5 000 to $30 000 per mile. The book, it is said, has been designed to meet the requirements of both experienced and inexperienced road men, and the collection of cost data and the tables, it is hoped, will prove useful to all who are engaged in road work. Considerable progress has been made in the practice of road design and construction since the publication of the first edition of this work, and this has necessitated a thorough revision of the subject-matter. The authors, therefore, have brought the material on top courses up to date and have added, it is stated, considerable data on tests, designs, costs, maintenance, and specifications, as well as approximately 100 pages of new matter, and a more complete and systematic index. The Contents are: Part I, Principles of Design: Grades and Alignment; Sections; Drainage; Foundations for Broken Stone Roads; Top Courses and Their Maintenance; Minor Points; Materials. Part II, Practice of Design and Construction: The Survey; Office Practice; Cost Data and Estimates; Notes on Construction; Specifications; Tables; Appendix A, Traffic Rules and Regulations of the State of Ohio; Traffic Regulations, State of New York; Index.

THE CONSTRUCTION OF ROADS AND PAVEMENTS.

By T. R. Agg. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 7 + 432 pp. New York, McGraw-Hill Book Company, Inc.; London, Hill Publishing Co., Ltd., 1916. $3.00.

This book was written, the preface states, to meet the need for a concise presentation of approved practice in the construction of roads and pavements and of the principles involved therein. It is intended primarily for use as a textbook by engineering students in a 2- or 3-hour course in highway engineering. The author, however, has also included typical designs and specifications, processes of selecting, testing, and mixing materials, descriptions of plant used, methods of construction, results of traffic, etc., as well as numerous tables and examples of practice in the different States, which, it is said, should make it valuable as a reference book for highway engineers. The Chapter headings are: The Development of Highway Systems; Surveys and Plans for Roads and Pavements; The Design of Rural Highways; The Construction and Maintenance of Earth Roads; Testing Non-Bituminous Road Materials; Sand-Clay Roads; Gravel Roads; Water-Bound Macadam Roads and Pavements; Concrete Roads and Pavements; Vitrified Brick Roads and Pavements; Wood-Block Pavements; Stone-Block Pavements; Bituminous Road and Pavement Materials; Dust Layers and Bituminous Carpets; Penetration and Mixed Macadam Roads and Pavements; Sheet Asphalt and Asphaltic Concrete Surfaces; Selection of Type of Surface for Rural Highways; Selection of Type of Pavement Surface; The Design of Pavements; Tests for Bituminous Road and Paving Materials; Glossary; Index.

TACHEOMETER SURVEYING

With Special Notes on Plotting, Care and Adjustment of Instruments, Field Work, and Calculations. By M. E. Yorke Eliot. Cloth, $7\frac{1}{2}$ x 5 in., illus., 10 + 148 pp. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1916. $2.00.

The author, it is stated, has endeavored in this book to give such information relative to the actual handling of instruments in the field and the methods adopted for working out the calculations in the office as will enable the engineering student to teach himself the practice which is based on theory. To that end the first four chapters of the book are devoted to preliminary explanations of the tacheometer and the methods of handling it, etc. Chapters V to VII, inclusive, describe the working out of an actual survey with the instrument, the operations, and the reasons for them, being explained step by step, from the selection and marking of the station points through the field work, the booking of figures, and office calculations made for the production of the plan, to the calculation of lines

and areas, etc., made from the data of the survey or from the plan itself. Explanations and illustrations of alternative methods are also given. Chapter VIII is devoted to the adjustments of the tacheometer, with a short description of recent and practical modifications of the instrument, and, in Chapter IX, the principles of construction of the slide rule are explained, as well as the application of the instrument to the reduction of field notes. The Contents are: Instruments; The Handling of Instruments; The Survey of a Simple Enclosure or Figure Bounded by Straight Lines; Determination of Heights and Horizontal Distances when Vertical Angles are Used; Field Work of a Contour Survey; Plotting; Calculation of Lines and Areas from Co-Ordinates; Adjustments of the Tacheometer; The Slide-Rule; Field Book; Index.

POCKET-BOOK OF USEFUL FORMULÆ AND MEMORANDA

For Civil, Mechanical and Electrical Engineers. By Sir Guilford L. Molesworth and Harry Bridges Molesworth. Twenty-seventh Edition, Revised and Enlarged, with an Electrical Supplement, by Walter H. Molesworth. Cloth, $3\frac{1}{2}$ x 5 in., illus., 7 + 936 pp. London, E. & F. N. Spon, Ltd.; New York, Spon & Chamberlain, 1916.

In the preface to this, the "Jubilee", edition, it is stated that fifty years have elapsed since the first edition of this Pocket-Book was published, at which time there were few, if any, engineering schools or textbooks. Progress in every branch of engineering has been enormous in these fifty years, and the authors, it is said, have spared no pains to keep pace, in this edition, with such advance. The contents, as stated in the title, consists of concise and comprehensive formulas and tables for the use of the civil, mechanical, and electrical engineer in his every-day work, gathered from many sources and bound in convenient form for carrying in the pocket. A partial list of Contents is: Levelling, Surveying, Latitude and Longitude; Strength and Weight of Materials; Earthwork, Brickwork, Masonry, Arches and Tunnels; Struts, Columns, Beams, Floors and Roofs; Girders and Bridges; Railways and Roads; Hydraulics, Canals, Sewers, Waterworks, Docks, Irrigation, Breakwaters, Diving and Dredging; Heat, Light, Colour and Sound, Ventilation, Warming, Refrigeration and Gas; Laws of Motion, etc.; Mill-work, etc.; Workshop Recipes; Miscellaneous Machinery, etc.; Steam; Steam, Oil, and Gas Engines; Animal Power, Water Power, and Water Motors; Wind, Windmills, and Pneumatic Machines; Ships and Steam Navigation; Gunnery, Projectiles, etc., Buoys and Moorings; Chimneys, etc.; Aeronautics, etc., etc.; Electrical Supplement; Index.

FOWLER'S MECHANICAL ENGINEER'S POCKET BOOK, 1916.

Edited by William H. Fowler. Eighteenth Annual Edition. Cloth, 6 x 4 in., illus., 66 + 576 pp. Manchester, England, Scientific Publishing Co., 1916. 2 shillings 6 pence. (Donated by The Norman, Remington Co.)

This work is a companion volume to "Fowler's Electrical Engineer's Handbook", and includes miscellaneous tables and formulas as well as much other valuable data for the use of the mechanical engineer. The Contents are: Steam Boilers and Fittings; Fuels and Combustion; Steam Engines, Steam Turbines, Locomotives; Steam Tables; Valves and Valve Gears; Internal Combustion Engines; Hydraulics; Pumps and Pumping Arrangements; Gearing and Lubrication; Hoisting and Lifting Machinery; Iron and Steel; Metals and Alloys; Beams and Pillars; Springs; Chemistry; Ventilation and Heating; Index.

FOWLER'S MECHANICS' AND MACHINISTS' POCKET BOOK, 1916.

Edited by William H. Fowler. Eighth Annual Edition. Boards, 6 x 4 in., illus., 50 + 460 pp. Manchester, England, Scientific Publishing Co., 1916. 7 pence. (Donated by The Norman, Remington Co.)

In a secondary title it is stated that this volume contains a synopsis of practical rules for fitters, turners, millwrights, erectors, pattern makers, foundry-men, draughtsmen, apprentices, students, etc., thoroughly revised and brought up to date. The Contents are: Handy References and Tables, Calculators; Materials Used in Machine Construction; Machine Tool Design; Metal Cutting Tools, Milling Cutters; High-Speed Tool Steels, Drilling and Boring Metals; Screw Threads, Screw Cutting, and Taper Turning; Emery and Emery Wheels, Shop Practice; Gearing, Rope, Belt, and Chain Driving; Lifting Ropes and Chains; Index.

FOWLER'S ELECTRICAL ENGINEER'S POCKET BOOK, 1916.

Edited by William H. Fowler. Sixteenth Annual Edition. Cloth, 6 x 4 in., illus., 50 + 512 pp. Manchester, England, Scientific Publishing Company, 1916. 2 shillings 6 pence. (Donated by The Norman, Remington Co.)

This book, it is stated, contains exhaustive information on electrical engineering facts and data, thoroughly revised and brought up to date. The Contents are: Miscellaneous Tables, etc.; Magnetism and Magnetic Data; Conductors and Insulating Materials; Electric Lighting and Wiring; Comparison and Measurement of Resistances; Electrical Measuring Instruments; Electricity Meters; Primary and Secondary Batteries; Dynamos and Motors; Alternate Electric Currents; Alternators; Transformers; Alternate Current Motors; Switchboards, Circuit Breakers, and Lightning Arresters; Power Transmission and Distribution; Converting Plant; Electric Traction; Rules and Regulations; Index.

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Hydraulic Flow Reviewed: A Book of Reference of Standard Experiments on Pipes, Channels, Notches, Weirs, and Circular Orifices, Together with New Formulæ Relating Thereto. By Alfred A. Barnes. London, 1916.

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DEATHS

Appleton, Thomas. Elected Member, April 4th, 1883; died August 3d, 1916.

Canfield, Edward. Elected Member, December 3d, 1879; died August 18th, 1916.

Hider, Arthur. Elected Member, September 7th, 1881; date of death unknown.

Patterson, William Rodney. Elected Member, May 4th, 1909; died July 20th, 1916.

Tabor, Ernest Frederick. Elected Member, May 1st, 1907; died August 20th, 1916.

Total Membership of the Society, September 7th, 1916, 8 041.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(July 24th, to September 1st, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age*, New York City, 10c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.

(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron*, Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 20c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Iron Tradesman*, Atlanta, Ga., 10c.
(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal*, Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas*, San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung*, Leipzig, Germany.
(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal*, Engrs.' Club of St. Louis, St. Lous, Mo., 35c.
(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Vibrations and Oscillations of Bridges.* D. H. Remfry. (23) Serial beginning June 23.
Electric Power Input for Railroad Bridges Movable in a Vertical Plane. Burton R. Leffler. (85) July.
Discussion on Impact.* L. N. Edwards. (85) July.
Pretoria Avenue Bridge, Ottawa.* L. McLaren Hunter. (96) July 6.
The Economical Section for Short Span, Reinforced Arches Carrying Light Highway Loadings.* C. B. McCullough. (86) July 26.

* Illustrated.

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Bridges—(Continued).

Bensalem Avenue Concrete Arch Bridge, Philadelphia, Pa.* Jonathan Jones. (86) July 26.
Large Bridge Pier Construction Using Steel Forms.* (86) July 26.
Military Ponton Bridges Used in the United States Army.* Percy E. Barbour. (13) July 27.
New Railway Bridge over Ohio at Metropolis, Ill.* (13) July 27.
Solid Floors for Through Girder Spans.* (15) July 28.
Abandoned Bridge Difficult to Destroy.* J. H. Weatherford. (14) July 29.
New Wood Floor Construction for Bascule Bridges.* (13) Aug. 3.
A Semi-Floating Highway Bridge.* (14) Aug. 5.
Plate-Girder Cantilever Bridge.* Arthur G. Hayden. (13) Aug. 10.
New Three-Track Bascule Bridge at Chicago.* (15) Aug. 11; (18) Aug. 12.
Steel Spans and Concrete Arches Combined to Form Unusual Bridge at Ninetieth Street, Cleveland.* (14) Aug. 12.
Mission Bridge in Canadian Northwest Designed as Adornment to its Location.* John F. Greene. (14) Aug. 12.
South Cantilever Arm of Quebec Bridge Completed.* A. J. Meyers. (13) Aug. 17; (96) Aug. 17.
Theory of Displacements Applied to Analysis of Suspension Bridges.* C. S. Whitney. (14) Aug. 19.
Overflow Bridges, Types of Overflow Bridges used in M'Lennan County, Texas.* William C. Davidson. (86) Aug. 23.
Popolopen Steel Arch in the Hudson Highlands.* (13) Aug. 24.
Condition of Iron in the Old Keokuk Bridge.* George C. Hinckley. (13) Aug. 31.
Quebec Suspended-Span Hoisting Details Completed.* A. J. Meyers. (13) Aug. 31.
Straightening 70-Ft. I-Beams Bent by Flood.* (13) Aug. 31.
Note sur le Calcul des Arcs Elliptiques Encastrés. G. Guillaumin. (43) Nov., 1915.
Strassenbrücke über die Sihl bei Scheeren.* Fritz Locher. (107) July 1.

Electrical.

Recent Street Lighting Problems and Developments. J. R. Cravath. (4) June.
Some Experiences in Connection with Chicago's Street Lighting System. Arthur C. King. (1) June.
Graphic Determination of Hysteresis Loss.* A. Castex. (73) July 14.
Power Requirements and Resources of New South Wales.* William Corin. (Abstract of paper read before the Elec. Assoc. of Australia.) (73) Serial beginning July 14.
Instrument Transformers.* Chas. C. Garrard. (73) Serial beginning July 14.
Adjustable-Speed Polyphase Induction Motors.* (26) July 14.
The Effects of Power Factor on Voltage Regulation.* F. A. Annett. (64) July 18.
New Development in Switchgear Control.* A. G. Collis. (12) Serial beginning July 21.
A New Electrolytic Interrupter.* C. A. Oldroyd. (19) July 22.
Power System of the Syracuse Lighting Co.* Norman G. Meade. (64) July 25.
Effects of Eddy Currents.* W. N. Cross. (64) July 25.
Construction of an Electrical Subway Crossing on a Highway Bridge.* C. M. Hartley. (86) July 26.
Charging Electric Vehicle Batteries. (12) July 28.
Some Mechanical Analogies in Electricity and Magnetism.* W. S. Franklin. (From *General Electric Review*.) (73) July 28.
Electrolytic Chlorine for Laundries.* H. P. Hill. (27) July 29.
Skin Effect and its Practical Treatment. (Transmission wires.)* Clem A. Copeland. (111) Serial beginning July 29.
Rates for Residence Lighting, Compilation of Population Served at Various Minimum Charges and Maximum Net Rates.* (27) July 29.
Steel Conductors for Transmission Lines.* H. B. Dwight. (42) Aug.
Why Motor Drive is Best.* William H. Easton. (9) Aug.
The High-Voltage Potentiometer.* Harris J. Ryan. (42) Aug.
Insulator Failures under Transient Voltages.* W. D. Peaslee. (42) Aug.
Testing for Defective Insulators on High Tension Transmission Lines.* B. G. Flaherty. (42) Aug.
Underground Distribution Systems. G. J. Newton. (42) Aug.
Temperature Rise of Insulated Lead-Covered Cables.* Richard C. Powell. (42) Aug.
A Distribution System for Domestic Power Service from Commercial and Engineering Standpoints. Carl H. Hoge and Edgar R. Perry. (42) Aug.
An Artificial Transmission Line with Adjustable Line Constants.* C. Edward Magnusson and S. R. Burbank. (42) Aug.
Characteristics of Admittance Type of Wave Form Standard.* Frederick Bedell. (42) Aug.
Three Thousand Volt Direct Current Substations.* (64) Aug. 1.

* Illustrated.

Electrical—(Continued).

Alternator Excitation and Exciters.* Gordon Fox. (64) Aug. 1.
Tests on Oil-Switches.* Bruno Bauer. (73) Aug. 4.
A 3 000 to 5 700-Kva. Substation Built at Low Cost.* L. J. McKenzie. (27) Aug. 5.
Reckoning with Costs of Superseded Equipment.* Edwin D. Dreyfus. (27) Aug. 5.
Long-Distance and Cable Telephony (Underground and Submarine).* B. S. Cohen and J. G. Hill. (73) Serial beginning Aug. 11.
Iron and Steel Electrical Conductors.* T. A. Worcester. (Abstract from *General Electric Review.*) (12) Aug. 11.
New Low-Resistance Standards. C. V. Drysdale. (73) Aug. 11.
Electric Signaling with Bare Wires.* (Abstract from Report of the British Home Office.) (73) Aug. 11.
Graphical Solution of Transmission Line Problems.* T. A. Wilkinson. (27) Aug. 12.
The World's Largest Direct-Current Station.* Fred Allison. (27) Aug. 12.
Ventilating Electric Machines.* Gordon Fox. (64) Aug. 15.
Power Factor Meters.* (12) Aug. 18.
Earth Connections for Telephone Exchanges.* W. H. Grinsted. (73) Aug. 18.
Adapting Direct-Current Motors to Changed Conditions.* H. L. Smith. (Abstract from *Electric Journal.*) (73) Aug. 18.
The Air-Gap Field of the Polyphase Induction Motor.* F. T. Chapman. (73) Serial beginning Aug. 18.
The Manufacture of Electric Cables. (47) Aug. 18.
A Method of Studying Edison Distribution Systems.* C. E. Bennett. (27) Aug. 19.
Analysis of Frequency in Oscillatory Circuits.* G. W. O. Howe. (27) Aug. 19.
Mechanical Strength of Copper Wire Splices.* E. R. Shepard. (27) Aug. 19.
Magnetic Permeable Cylindrical Conductors.* Clem A. Copeland. (111) Aug. 19.
Experience with Electric Heating of Dwellings.* J. D. Ross. (27) Aug. 26.
Building up a Big Power Load on an Electric Railway.* (17) Aug. 26.
Modern Applications of Electricity to Medicine.* Donald K. Lippincott. (111) Aug. 26.
Die neuen Telephon-Zentralen in Zürich.* (107) July 22.

Marine.

The Yield of Riveted Connections in Shipbuilding. Arthur R. Liddell. (12) July 14.
Design of an Ideal Thrust Block.* C. P. Tanner. (Paper read before the Inst. of Marine Engrs.) (47) July 14.
5-Ton Electric Cranes for Shipyards.* (11) July 21.
Deflection of Ships Due to Temperature Influence.* K. Suyehiro. (Paper read before the Japanese Inst. of Naval Archts.) (11) July 28.
The Electrical Equipment of a Modern Foreign Submarine Boat.* Norman H. Wood. (26) Serial beginning Aug. 4.
Illumination in the Navy (U. S. A.) C. S. McDowell. (73) Aug. 18.
Les Débuts de la Navigation Transatlantique en France. E. Evers and A. Mallet. (32) Jan.
La Commande Electrique des Gouvernails.* A. Foillard. (33) July 29.

Mechanical.

The Electrically Driven Gyroscope and its Uses.* Elmer A. Sperry. (2) July.
Diesel Engines.* F. Reginald Phipps. (114) July.
On the Formation of Steam.* James Scott. (21) July.
The Formation of Aromatic Compounds from the Cracking of a Gas Oil.* Gustav Egloff and Thomas J. Twomey. (105) July 1.
Boiler-Room Cost Curves.* J. D. Morgan. (64) July 4.
Burning Coke Breeze.* (64) July 4.
Operating Costs for Municipal Gas-Engine Plant.* H. T. Melling. (64) July 4.
Developing Efficiency in Central Stations.* C. M. Rogers. (64) July 4.
Commercial Motor Vehicles for Railway and Industrial Purposes.* (23) July 7.
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Operating Conditions at Newark, Ohio, Power Plant.* W. O. Rogers. (64) July 18.
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PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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A METHOD OF DETERMINING A REASONABLE SERVICE RATE FOR MUNICIPALLY OWNED PUBLIC UTILITIES

By J. B. Lippincott, M. Am. Soc. C. E.

To be Presented October 18th, 1916.

Synopsis.

The physical development of the Western States is far from complete, and although the larger municipalities may be able to finance utilities satisfactorily, in a manner commensurate with their needs, the growth, particularly of the outlying districts and smaller towns, will await largely the investment of private capital. In order to advance, all communities must have light, transportation, telephone service, water, etc. These utilities, whether privately or publicly owned, are essential to development. In California, at present, exclusive of steam railroads, 95% of the value of the public utilities is in private ownership.

In addition to the advisability of the public administration of both publicly and privately owned utilities being conducted on a fair and reasonable basis, it is essential that this administration should be such as will encourage the investment of private capital therein. If the rates for service of publicly owned utilities are too low, and

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

deficits are made up from the general tax funds, such administration is unfair to privately owned utilities and will tend to discourage the investment of private funds therein, in States practicing this policy. Of late, and at present, in California, voluntary investment in privately owned utilities is awaiting the determination of public policy relative thereto.

The rates for service of a publicly owned utility should be fixed in the same manner as that for one privately owned, that is, it should be based on operation, plus depreciation, plus reasonable interest on value. Any surplus resulting from such administration should be deposited in the public treasury of the city to the credit of the general tax fund.

Public utilities are the framework on which the commonwealth is developed. All classes of citizens desire ready access to transportation, light, water, power, and telephones, in order to develop their communities economically. Excluding steam railways, 95% in value of the public utilities of California are privately owned. Statistical tables (Tables 1 and 2) show that not more than 10% of the State of California (after omitting the area of the desert lands south of Owens Lake) is developed as to density of population, and about 20% as to value. The wealth per capita is high. It must be borne in mind that the growth of a community, and its attendant wealth, are largely dependent on public utilities; and the investment of private capital in these enterprises should be fostered and encouraged with a view to the further growth of the State. A new and undeveloped State, such as California, manifestly cannot publicly build all its utilities.

There has been difficulty in obtaining the data on the relative value of municipally and privately owned utilities in California. That of the privately owned utilities for 1912 is taken from the report of the State Railroad Commission. This covered all the privately owned utilities, with the exception of the steam railroads, which have not been pro-rated for the different States. The best information on the municipally owned utilities is found in the report of the California State Controller for 1914. This report gives statistics relating to the municipal utilities in the State. For some of them, however, the values were not stated, and some were incomplete, as in the case of the Los Angeles Water Department, where the aqueduct was omitted. To

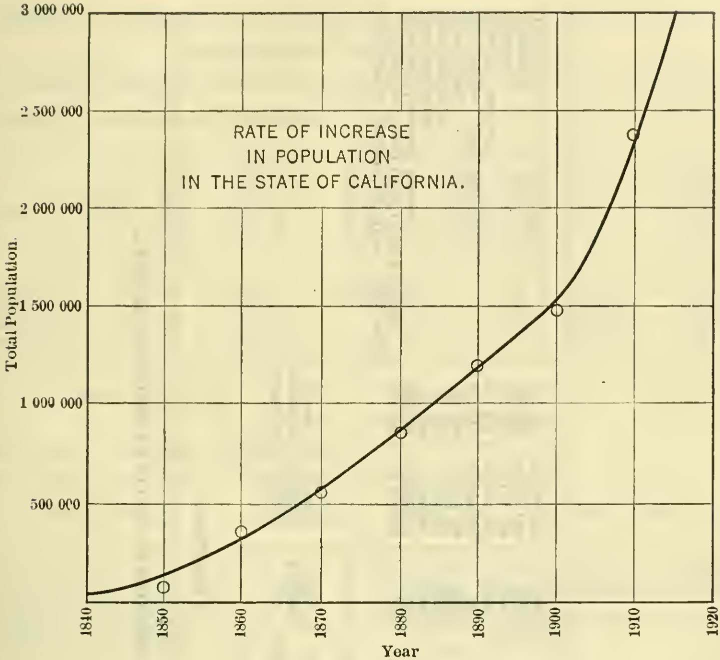
RATE OF INCREASE
IN POPULATION
IN THE STATE OF CALIFORNIA.
Total Population.
3 000 000
2 500 000
2 000 000
1 500 000
1 000 000
500 000
1840
1850
1860
1870
1880
1890
1900
1910
1920
Year

FIG. 1.

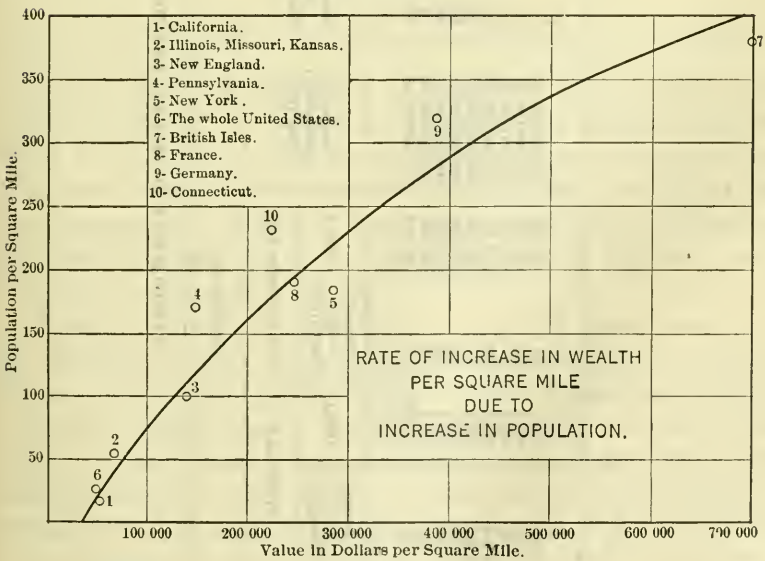
1- California.
2- Illinois, Missouri, Kansas.
3- New England.
4- Pennsylvania.
5- New York.
6- The whole United States.
7- British Isles.
8- France.
9- Germany.
10- Connecticut.
RATE OF INCREASE IN WEALTH
PER SQUARE MILE
DUE TO
INCREASE IN POPULATION.
Population per Square Mile.
400
350
300
250
200
150
100
50
100 000
200 000
300 000
400 000
500 000
600 000
700 000
Value in Dollars per Square Mile.

FIG. 2.

TABLE 1.—COMPARATIVE STATISTICS FOR THE STATE OF CALIFORNIA.

	POPULATION.				VALUATION.				
						Per square mile.		Per capita.	
	Area, in square miles.	Total population.	Per square mile.	California. Percentage.	Total, based on assessed valuation.	Total.	California. Percentage.	Total.	California. Percentage.
California (excluding from the area desert lands south of Owens Lake)	124 250	2 377 549	19	100	$6 622 000 000	$53 200	100	$2 790	100
Illinois, Missouri, Kansas	208 243	10 622 875	51	37	14 398 850 000	68 900	78	1 350	206
New England	66 424	6 552 681	99	19	9 345 475 000	140 000	38	1 423	196
Pennsylvania	45 126	7 655 111	170	11.2	6 685 500 000	148 000	36	872	319
New York	49 204	9 113 279	185	10	14 035 300 000	286 000	19	1 540	181
The whole United States	3 617 673	91 972 266	25	75	187 739 000 000	51 900	104	2 040	136
The British Isles	121 331	46 064 738	380	5	85 000 000 000	700 000	7.5	1 840	151
France	207 054	39 601 509	191	10	50 000 000 000	241 500	22	1 260	220
Germany	208 780	66 715 000	320	6	80 000 000 000	383 000	14	1 200	232
Japan	147 655	52 985 423	359	5	....	....	....	......	....

TABLE 2.—RELATIVE VALUE OF PUBLICLY AND PRIVATELY OWNED UTILITIES IN CALIFORNIA IN 1912.

Total population of incorporated cities in California = 2 340 242.

PUBLICLY OWNED UTILITIES.

Class of utilities.	Number of plants.	Population of cities reported.	Value of plants in cities reported.	Population of cities owning plants with no value reported.	Total population.	Estimated total value of utilities.
Water	81	1 033 410	$58 633 904	85 936	1 119 346	$67 770 000
Electric	14	109 819	1 884 709	3 700	113 519	1 950 000
Gas	1	6 000	....	....	6 000	42 000
Wharves	6	978 127	4 091 440	....	978 127	4 091 440
Total						$73 853 440

PRIVATELY OWNED UTILITIES.

Class of utilities.	Number of plants.	Value.	Total values.
Street railways	30	$454 892 593	Publicly owned.... $73 853 440
Water	238	204 000 917	Privately owned.... 1 445 319 496
Gas and electric companies	113	525 677 587	
Telephone and telegraph	81	253 357 061	Ratio of public to private 5.1 per cent.
Wharfinger warehouse companies	37	7 391 338	
Total		$1 445 319 496	

cover this latter item, $26 000 000 is added here. The values for the cities omitted are interpolated by computing the average value per capita for all the cities given and applying this figure to the population of the cities omitted. The Controller's report makes no mention of the San Francisco City Railways. These results are tabulated. Excluding the steam railroads, the value of municipally owned utilities is only 5.1% of those privately owned.

There is of late, in the United States, a decided trend toward public ownership of public utilities, especially by municipalities. In California, both the Railroad Commission and the Courts have recently prevented privately owned public utilities from entering a municipality which is already being served adequately by another privately owned public utility of the same class. Yet municipalities of this State are exempt from such legal restrictions, and our highest Federal Courts have confirmed the right of the public to invade the field of a privately

owned utility in competition, without the legal obligation either to condemn or purchase the privately owned plants. The people have this inherent right to serve themselves, and though the public should be able to enjoy the profit and security of their own service, there is a broad equity involved that requires the protection of the privately owned plant which has been built in good faith and is being operated under public regulation so that its rates are just and its service adequate. It would be a public misfortune to confirm the impression that private investments are to be over-ridden unfairly and in such a way as to injure legitimate investment. If unfairness is practiced in our larger centers of population, having substantial bonding resources, it is apt to delay greatly the development of the back country, where public credit for large enterprise is lacking.

Rate-fixing commissions must be given credit for stabilizing the value of public utilities bonds. Stockholders have suffered severely, and in many instances they should. In California public utility corporation bonds, approved by State authority, are now sought after. The bondholders are usually only loaners of money. It requires stock buyers to build extensions and new works. The writer feels that it would lead to the more rapid development of the State if the Commission's policy were more liberal in the fixing of valuations, and especially in the permissible rate of interest return allowed. Private capital invested in utilities should be protected against unjust competition of publicly owned utilities. The building of private utilities in California has been practically stopped until it becomes more apparent what this public policy is to be. In Wisconsin this stage of State development has been passed.

In so far as known, neither the California Railroad Commission, nor the California Courts have ever expressed themselves as to what would be a reasonable rate for a publicly owned utility to charge its consumers. The Wisconsin Railroad Commission has reviewed this question, and the trend of its decisions is to the effect that the rate should be fixed in the same manner as though the utility were privately owned, the theory being that, where a publicly owned utility is in competition with one privately owned, it should not be given such preference as to result in the destruction of the value of the private plant. For instance, if a city goes into competition with privately owned plants for the sale of electric energy within its boundaries, and

the interest on the bonds and the sinking fund is paid from the general tax, it would put such a handicap on the privately owned plant as would ultimately work its destruction.

The rates for municipally owned utilities in California have often been fixed rather as a political, than as an economic, question, it being a popular and easy road to public favor to advocate the reduction of any rate.

The rate for a public utility service should be based on the fair value of the properties used and useful in the service, irrespective of whether the plant is privately or municipally owned. The municipal plant should be viewed as an investment of public funds by the city, and it should be operated with the view of obtaining a profit on the investment.

The rate for a privately owned utility should be adequate to provide, first, for the expenses of operation and maintenance, second, for depreciation, and third, for an interest return on the fair value of the property. This last item will provide interest on the bonded debt and any profit accruing to the owner. With a municipally owned utility, in addition to these expenses, there is a bond redemption fund. It has no counterpart in a privately owned plant, as its bonds are seldom retired, but, on maturity, are taken care of by a refunding process. In California, however, the law requires that municipalities retire one-fortieth of the bond issue each year.

There are four classes of people who should assist in bearing the cost of a municipally owned public utility:

First.—The city as a whole, or the government;

Second.—The consumer;

Third.—The owner of vacant lots;

Fourth.—The real estate promoter who desires extensions made to new subdivisions.

First.—The City's Share of the Expense.—The municipality should contribute from the general tax fund for the cost of all public uses of water, notwithstanding the fact that the origin of the fund is usually from the general tax budget. The city should also provide from the general tax budget the annual contributions to the bond redemption fund for the utility. If the municipality's credit has been used in the issuance of bonds for the purchase or construction of the utility

plant, then the refunding of these bonds from the general tax budget is virtually payment for the plant by the city as a whole.

Second.—The Consumer's Share of the Expense.—The consumer should, manifestly, pay for the operation and maintenance of the system, and, if the municipally owned utility is to be treated on the same plane with one privately owned, then it follows that the depreciation account and interest on the fair value of the property should be also charged to the consumer. To deduct from the rates the depreciation and interest would put such a handicap on competing privately owned utilities that they probably could not live. This situation, however, is one that cannot be treated by a hard and fast rule. For instance, if a municipality is looking broadly into the future for its public necessities, as is being done by the Cities of Santa Barbara and Los Angeles in the building of their aqueducts, and the depreciation and interest charges on these large expenditures are put solely on the present consumers, it may result in a rate that would prevent adequate and desired uses of the utility. Apparently, some latitude must be exercised in every instance, in determining how this distribution should be made, in order to obtain a rate which is a feasible operating one.

Assuming that the city can borrow money on its bonds at 5%, and that a reasonable service rate for the utility will provide interest on the fair value of the property at 7%, there accrues a 2% differential which is in effect the profit in operating the utility. This profit should be expended in the ordinary extensions and betterments of the system, so as to avoid the necessity for frequent bond issues to make these improvements. These, in fairness, should be paid for by appropriations by the city council from the general tax fund. However, those who have had to do with these matters know that such allotments of money cannot be obtained, as a practical working proposition. Only when a large and substantial improvement is to be made should it be done by means of a bond issue. If any surplus accrues from the profit of the system, over and above the expenditures for improvements and betterments, this surplus should be turned into the general funds of the city, for the purpose of reducing taxes rather than rates.

There are two classes of consumers under the municipally owned plant, those who are not taxpayers in the community, and those who are. The consumer who does not contribute taxes is paying a fair price for the service received, and is not entitled to have the cost of

this service reduced simply because he happens to be temporarily a resident in a community owning the utility. He has no investment there, and has assumed no liabilities on its account.

Property owners have guaranteed the payment of public debts. If the bond redemption fund is provided for from the general tax levy, all taxpayers are proportionate owners of the utility. A share of the profits accruing from this ownership should revert to the taxpayers through the general fund, so that the consumer who is a taxpayer receives an indirect benefit from the ownership of the utility in this way. This system would encourage property ownership.

Third.—The Vacant Lot Owner's Share of the Expense.—The vacant lot owner in our Western towns is a source of great expense and burden to all utilities. It is probable that one-half the mileage of distribution mains is caused by his speculation in land values. The utility is standing ready to serve at any time, and the value of the vacant property depends largely on its privilege to be benefited thereby. Unless a charge is assessed against vacant lot owners, they are securing benefits without adequate contributions to the expense of the plants. Some system of assessment on such vacant property on a front-foot basis should be developed to cover this element, as is often done in street paving and sewer work.

A portion of the cost of building the utility is borne by the vacant lot owner in that he is a taxpayer and has assumed the liability for the debts of the community. He enjoys the broad and general benefits that result from the operation and ownership of the plant, which the consumers alone should not pay for. There are many vacant lots in the old and established portions of the city where the plant has long been built, and such lot owners cannot be assessed as in the case of an extension to a new subdivision. Possibly they should be charged an assessment each year, which should go into a fund for ordinary betterments of the system or into the public treasury.

Fourth.—The Real Estate Promoter's Share of the Expense.—The real estate promoter is continually making new subdivisions and petitioning the utilities, whether publicly or privately owned, to make extensions therefor. With privately owned utilities it is usually demanded that the promoter shall pay for the cost of the extensions. This policy has also been followed in many of the publicly owned utilities, but it has resulted in political agitation, and has been vigorously

resisted by the interests who are active in their efforts to speculate on the community.

The vacant lands exploited by the real estate promoter may be divided into two classes: first, those lying within the corporate limits of the municipality owning the public utility; and second, those outside these corporate limits.

In the first instance it would be equitable to require the owner of the property to pay a frontage tax to cover the cost of the distribution system fronting the property in question, this contribution to be returned when this part of the plant is on an earning basis. It would not be proper to charge a portion of the cost of the mother plant against these extensions, because the property will already have paid some proportion of the cost thereof in taxes, and will pay more as its value increases. The assessments for the extensions to the new subdivision within the corporate limits of the city should be in the nature of a temporary donation.

If the lands to be exploited are outside the corporate limits of the community, it would again be just to require the owner temporarily to advance the funds necessary to make the extensions. So far as concerns storage reservoirs and conduit systems, or any of the mother plant built for the distant future, and which may equitably be assumed to involve the promoter's lands, a portion of the cost of this excess capacity should justly be charged to the promoter.

This whole problem cannot be solved rigidly with a rule which will apply to all cases. There is, however, the necessity for outlining some general theory, on which municipalities should proceed. Even if it is clearly defined, and is endorsed by high authority, there will be the practical political difficulties of fixing and maintaining rates at a just point. Obstacles will have to be overcome in case it is necessary to increase a rate. There is great inertia inherent in communities, and this it is necessary to prevail against, in order to make a change of any sort.

Our cities are becoming great business concerns, and should be managed fairly and scientifically, not only for the interests of the citizens therein, but also for those who have financed in one way or another their utilities and early development.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

A COMPLETE METHOD FOR THE CLASSIFICATION OF IRRIGABLE LANDS

By F. H. Peters, Assoc. M. Am. Soc. C. E.

To be Presented November 1st, 1916.

Synopsis.

This paper deals with the classification by the Dominion Government of a very large area of irrigable land developed by the Canadian Pacific Railway Company in the Province of Alberta. The reason for undertaking the work is stated. The climatic, soil, and crop conditions of the area under discussion are described, and, as governed by these, the basis of the classification is stated. Then the actual manner in which the classification of the land was made is described in detail.

The Reason for Government Classification.—The development of the Western Section irrigation block was carried out by the Canadian Pacific Railway Company. Construction was started in 1903, and the project was practically completed in 1910. The development covers a gross area of about 1 037 000 acres, of which more than 223 000 acres are irrigable. There are 17 miles of main canal, 254 miles of secondary canals, and 1 300 miles of distributaries. The total cost of construction has been \$4 325 000, and it is estimated that a further expenditure

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

of $1 500 000 will be necessary to replace wooden structures with concrete. About 66% of the irrigable lands have been sold.

The law in force in Alberta, and under the provisions of which the project was constructed, is the Dominion statute entitled the Irrigation Act.

This Act contains a clause to the effect that, before a water license is granted to any person or corporation, a certificate must be issued, by the Chief Engineer appointed under the Act, certifying "that the works as constructed are capable of carrying and utilizing a stated quantity of water". It is necessary to certify to the carrying capacity of the works because this has a fixed ratio to the irrigable area, based on the legal duty of water, which is fixed. The Minister of the Interior, who is created by the Act the high executive officer of the Crown, decided that in the case in question the fullest intent of the quotation above should be carried out and ruled that "utilization" should be held to mean "beneficial utilization".

This decision made it necessary to make a complete classification of all the irrigable land, and this had to be based on a rigid definition of the words "beneficial use" in terms of dollars and cents.

Determination of the Basis for Classification.—It was admittedly a difficult problem to assign a cash value to the term "beneficial use", which made necessary a balancing of the added returns of irrigation against the added cost of irrigation—both in comparison with dry farming.

The so-called "dry farming" method of agriculture was generally practiced in the Province, and the value of the returns from this method of agriculture were known. The value of returns from irrigation agriculture in the district was not known, because there had been very little actual irrigation. It was necessary to make a conservative estimate of the added returns over dry farming due to irrigation.

The added cost of irrigation was considered to be made up of four items: the additional first cost of the irrigable land over non-irrigable land; the annual charge for water; the ordinary cost of smoothing and leveling the land to allow of an even spreading of the water; and the concentrated cost of reaching, from the head-gate, certain areas of land which, being cut off by a depression, required embankment or flume construction, or, being in a depression, required drainage. The

first two items were known, and the average cost of smoothing and leveling was estimated.

The governing element in the basis of the classification, which will be described in detail later, was the item of concentrated cost.

In making an estimate of the added returns of irrigation, it was necessary, because of the lack of actual data for the district, to make a very broad study of all the essential features, and these are dealt with under the headings of "Climate", "Topography and Soil", and "Crops".

Climate.—The tract lies approximately 120 miles north of the International Boundary and 50 miles east of the foot-hills of the Rocky Mountains, and has a general slope from west to east. The elevation of the western boundary is about 3 300 ft. above sea level and that of the eastern end is about 2 900 ft.

The climatic conditions are very similar to those in Northern Montana and the higher valleys of Colorado, where irrigation has been practiced successfully for years. The average growing season between spring and fall killing frosts (32° Fahr.) is about 101 days.

Tables 1 and 2 show the temperature and precipitation for Calgary and Gleichen, which are nearly at the west and east ends of the tract, respectively. The irrigation season extends from May 1st to September 30th.

Topography and Soil.—The topography is generally rolling, with rather steep slopes which locally run up to 10 or 15 ft. in 100 ft. There are many cross-drainage lines, and, in order to avoid expensive crossings, the locators were forced to drop the elevation of the canals, thus losing command of some of the higher and better lands. The topography is somewhat smoother in the eastern than in the western portion of the tract.

The soil conditions over such a large area, of course, have a wide variation. Extreme conditions, varying from almost pure sand to very heavy clay, may be found, but, speaking generally, the soil is the usual clay loam commonly found on the prairies of the Northwest. As a whole, the area is overlaid with a surface soil containing a good proportion of humus, which proves very fertile. In general, the subsoil is a heavy clay, making it imperative to apply the irrigation water with care, in order to avoid water-logging the land. Local conditions where the soil is heavily impregnated with white alkali are found, but black alkali is rare. As will be indicated later, great care was taken

TABLE 1.—TABLE OF PRECIPITATION AND TEMPERATURE AT CALGARY, ALBERTA.

Year.	Precipitation, in Inches.		Mean Temperature, in Degrees, Fahrenheit.	
	Total for year.	Total for irrigation season.	For year.	For irrigation season.
1885	12.91	9.32	37.05	53.6
1886	11.32	5.98	38.04	56.2
1887	13.69	9.12	33.86	54.1
1888	17.51	11.29	35.15	54.6
1889	11.59	6.41	39.54	54.7
1890	14.94	10.86	35.68	54.5
1891	10.44	8.74	37.71	55.0
1892	7.91	5.13	36.12	53.6
1893	11.05	7.17	31.76	53.9
1894	11.71	8.02	37.17	55.3
1895	15.12	10.99	36.66	53.1
1896	16.05	8.12	36.00	55 6
1897	20.58	15.02	37.10	57.8
1898	15.58	11.84	37.80	56.6
1899	26.15	21.46	34.70	53.0
1900	17.57	12.18	38.60	54.1
1901	22.31	16.47	39.20	53.3
1902	34.57	30.75	37.00	52.7
1903	22.77	19.91	37.50	52.6
1904	11.89	8.71	36.90	54.2
1905	14.12	10.02	39.00	54.6
1906	16.24	13.50	39.30	55.6
1907	14.96	11.48	36.70	52.66
1908	18.25	15.68	40 69	56.02
1909	16.03	11.98	35.97	55.78
1910	11.79	8.53	37.88	54 98
1911	19.38	15.08	35.67	52.68
1912	21.38	16.54	39.45	54.14
1913	17.08	12.85	39.94	57.08
1914	17.71	8.97	40.52	58.02
Mean for period..	16.42	12.07	37.29	54.67

TABLE 2.—TABLE OF PRECIPITATION AND TEMPERATURE AT GLEICHEN, ALBERTA.

Year.	Precipitation, in Inches.		Mean Temperature, in Degrees Fahrenheit.		Remarks.
	Total for year.	Total for irrigation season.	For year.	For irrigation season.	
1903............	15.83	13.41	3	......	
1904............	10.22	7.09	37.09	55.08	
1905............	11.94	9.61	37.96	55.02	
1906.....	17.73	13.36	38.08	55.90	
1907............	....	....	......	......	
1908............	....	13.83	......	54.90	Records not complete.
1909............	20.51	17.13	34.62	55.82	
1910............	....	6.91	40.18	57.08	
1911............	....	10.88	......	53.56	
1912............	....	6.20	......	55.06	
1913............	.. .	10.16	......	......	
1914............	9.90	5.55	......	......	
Mean for period....	14.36	10.38	37.59	55.30	

in the classification to exclude as non-irrigable any areas in which the soil analysis showed this great enemy to irrigation to exist in dangerous quantity.

Crops.—The leading crops in the Province are hard wheat, oats, and barley. The hardier strains of alfalfa grow excellently under irrigation, and small fields throughout the tract produce from 3 to 4 tons per acre in two or three cuttings. Experimental plot work has indicated that a heavy yield of sugar beets, with a high saccharine content, can be raised under irrigation. The irrigation tract under consideration is so young in development as yet that no good general crop reports can be obtained. In the Lethbridge District, about 100 miles to the south, however, there are about 15 000 acres under the alfalfa crop which produce about 4 tons per acre under irrigation.

For purposes of comparison, the following points are noted with reference to this tract. The general elevation is about 2 850 ft.; the soil conditions are more favorable as regards texture and absence of alkali; the annual precipitation is about 2 in. less; and the annual mean temperature is about 4½° Fahr. higher.

The Dominion Government Experimental Farm at Lethbridge has kept records of the returns from irrigated and non-irrigated crops since 1908, and Table 3 has been compiled by using these actual returns and inserting the prices which were obtained each year, f. o. b. cars, at Lethbridge. This table must be accepted as showing results from plots on the experimental farm, which are no doubt higher than those obtained by the average farmer, but it is considered that the table shows truly the relative increase due to irrigation. To be indicative of the crops commonly raised under irrigation in the district, the table should include alfalfa and timothy hay.

Basis of Classification Adopted.—The basis of classification adopted was as follows: Land shall be classified as irrigable:

(1).—If it lies at a lower elevation than the point of delivery, after allowing a reasonable grade for a farm lateral.

The point of delivery shall be deemed to be a point 3 in. below the crest of the measuring weir at or within the farm boundary. Where this measuring weir is not at or within the farm boundary, the point of delivery shall be the elevation of full supply level in the lateral supplying the field outlet, and all measuring weirs shall be built in

TABLE 3.—RECORDS OF RETURNS FROM IRRIGATED AND NON-IRRI- AT LETHBRIDGE, ALTA.,

1908.			1909.			1910.			1911.		
Dry.	Irrigated.	Gain by irrigation.	Dry.	Irrigated.	Gain by irrigation.	Dry.	Irrigated.	Gain by irrigation.	Dry.	Irrigated.	Gain by irrigation.
											WHEAT,
Bushels, 34	34	0	29	37	8	15	29	14		Hailed.	
$30.94	30.94	0.00	27.55	35.15	7.60	12.81	24.76	11.95			
											OATS,
Bushels, 80	88	8	56	77	21	21	68	47		Hailed.	
$28.00	30.80	2.80	18.34	25.22	6.88	5.67	18.36	12.69			
											BARLEY,
Bushels, 55	60	5	41	64	23	12	42	30		Hailed.	
$20.35	22.20	1.85	15.32	23.92	8.60	5.64	19.74	14.10			
											POTATOES,
Bushels, 92	235	143	159	605	446	103	521	418	356	560	204
$41.40	105.75	64.35	71.55	272.25	200.70	46.35	234.45	188.10	160.20	252.00	91.80

accordance with the plan of farm weirs filed with the Commissioner of Irrigation and dated November 1st, 1908.

The grade of farm laterals, when a factor in land classification, will be considered reasonable:

(*a*) Where the natural slope of the ground is less than 0.10 ft. in 100 ft. at a rate not less than 0.05 ft. in 100 ft.;

(*b*) Where the natural slope of the ground is greater than 0.10 ft. in 100 ft. at a rate of not less than 0.10 ft. in 100 ft.;

(*c*) Where the slope of the ground is at or near the critical slope of 0.10 ft. in 100 ft. at either of the grades mentioned in clauses (*a*) and (*b*), such as good and reasonable practice demands.

GATED CROPS AT THE DOMINION GOVERNMENT EXPERIMENTAL FARM CANADA, FROM 1908 TO 1914.

1912.			1913.			1914.			Averages.		
Dry.	Irrigated.	Gain by Irrigation.	Dry.	Irrigated.	Gain by Irrigation.	Dry.	Irrigated.	Gain by Irrigation.	Dry.	Irrigated.	Gain by Irrigation.
"Red Fife."											
31	63	32	27	45	18	20	67	47	26	46	20
26.62	54.10	27.48	20.05	33.41	13.36	14.78	49.50	34.72	22.13	37.98	15.85
"Banner."											
77	145	68	73	115	42	49	113	64	59	101	42
26.08	49.12	23.04	19.71	31.05	11.34	14.64	33.76	19.12	18.74	31.38	12.64
"Claude."											
29	81	52	40	94	54	30	97	67	34.5	73.0	38.5
10.37	28.96	18.59	12.40	29.14	16.74	11.10	35.89	24.79	12.53	26.64	14.11
"Irish Cobbler."											
296	501	205	229	528	299	400	495	95	234	492	258
133.20	225.45	92.25	103.05	237.60	134.55	180.00	222.75	42.75	105.10	221.46	116.36

Extremely flat country may be irrigated by checks and flooding, and the grade of the farm lateral need not be considered in such cases, it being understood that the Minister of the Interior, or officers appointed by him, shall be the final judges of what constitutes "extremely flat country".

(2).—If such land can be reached by an estimated concentrated expenditure at one or more points, for embankments, flumes, etc., not in excess of $8 per acre for the land to be served and benefited through them.

(3).—If such land can be served by a second or other delivery at a cost not in excess of $8 per acre for the land to be served and benefited through them.

(4).—When lying in a depression, if it can be drained at a cost not exceeding $8 per acre, and is suitable, arable land which would be benefited by irrigation.

(5).—The prices to be made use of in estimating the cost of embankments, flumes, or other structures, shall be, unless otherwise ordered by the Minister of the Interior:

Earth fill or excavation......................12 cents per cu. yd.
Lumber in place on any structure..........$40 per 1 000 ft. b. m.
Rock rip-rap......................50 cents per superficial yard.

(6).—In all unusual or exceptional cases, which are not covered by the preceding paragraphs, the classification will be made by officers of the Department, under the direction of the Minister of the Interior, in a fair and reasonable manner, and will be based on the beneficial use of water.

Much attention was given to the question of the maximum slope permissible for land to be classified as irrigable, but this was not included in the official basis. The engineer in charge, in approving the classification, was guided by the rule that generally a maximum slope of 10 ft. in 100 ft. was permissible, and where very small areas only were concerned a maximum slope of 12 ft. in 100 ft.

As indicated under the heading, "Determination of the Basis for Classification", the classification was based on a cost of $8 per acre, but as this is a very crucial point, many details are given in order to explain just what the figure means.

Under the conditions of its land sale contract and water agreement, the Company delivers the water to at least one point on each parcel of land, usually of 160 acres, and the cost figure was applicable only to the added expenditure necessary for the farmer to distribute the water over the land. The figure was not a general one applied to the total irrigable area in each parcel, and including the ordinary costs of leveling and smoothing the land, but was the concentrated cost of reaching certain areas of land which, being cut off by a depression, required embankment or flume construction, or, being in a depression, required drainage.

The following study, which was made by the writer in examining the cost data before the basis of classification was adopted, will make the point quite clear.

Referring to Fig. 1, the area, *A-D-E*, can be easily irrigated without any high expenditures for flumes, embankments, etc., and the $8 figure does not recognize any expenditure necessary for this area. The area, *H-J-K-L*, is separated from the field outlet by a wide depression, and it required a costly raised ditch and flume to carry water from *B* to *C*. The basis of classification means that if the cost of the raised ditch and flume from *B* to *C* is less than a concentrated expenditure of $8 per acre on the area, *H-J-K-L*, then *H-J-K-L* shall be classed as irrigable. Again, the $8 figure does not recognize the ordinary costs of preparation necessary for the irrigation of *H-J-K-L* after the water has been conducted to *C*. Now, in truth, it would require a certain expenditure per acre in smoothing the land, building field laterals, distributaries, etc., to irrigate *A-D-E*, and similarly a certain expenditure per acre would be required to irrigate *H-J-K-L* after water had been conducted to *C*.

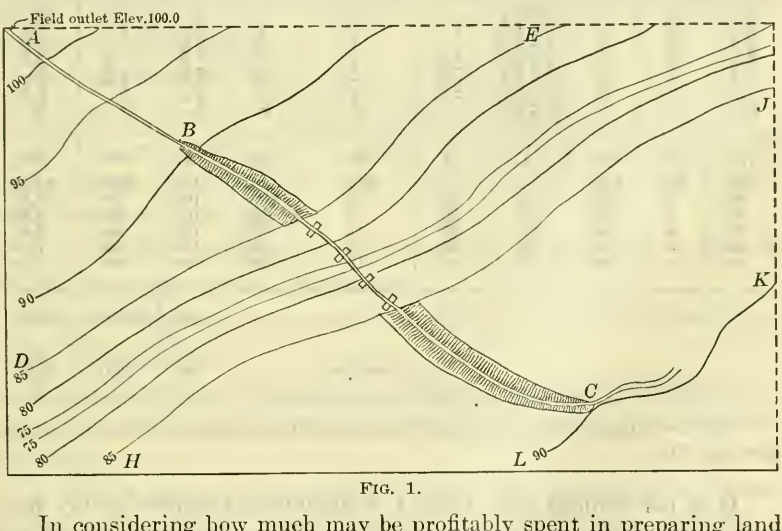


FIG. 1.

In considering how much may be profitably spent in preparing land for irrigation, it is usual to compute it at so much per acre for the whole parcel of land, this figure including all flumes, embankments, ditches, etc., and also the smoothing of the land to allow of proper irrigation.

The writer will now endeavor to show what the concentrated cost of $8 per acre means for different cases, and for the average case, couched in the usual terms, as explained in the foregoing paragraph.

If it is assumed that the average piece of land will require an expenditure of $4 per acre for smoothing, ditches, etc. (there being no clearing of any kind necessary in this district), and if this is combined with the concentrated cost of $8 per acre, it is seen immediately that the actual total cost of preparing any land which requires the "concentrated" expenditure is really $8 plus $4, or $12 per acre. It must be realized that in every parcel of land, considered as a unit, there will be a varying proportion which can be prepared for irrigation with an expenditure of only $4 per acre, and of other land which will require in addition to this the "concentrated cost" expenditure of $8 per acre.

TABLE 4.—Cost per Acre for Structures and Preparation of Land for Irrigation.

No. of acres of good land.	Cost per acre.	Total cost.	Percentage of land requiring concentrated expenditure.	Number of acres.	Cost per acre.	Total cost.	Grand total, in acres.	Grand total cost.	Average cost per acre.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
100	$4	$400	0	0	$12	0	100	$400	$4.00
90	4	360	10	10	12	$120	100	480	4.80
80	4	320	20	20	12	240	100	560	5.60
70	4	280	30	30	12	360	100	640	6.40
60	4	240	40	40	12	480	100	720	7.20
50	4	200	50	50	12	600	100	800	8.00
							600	$3 600	$36.00
					Averages............		100	$600	$6.00

Note.—Average cost per acre for structure and preparation of land for irrigation, say, $6.

It is not claimed that Table 4 is absolutely accurate in any way, but it shows that, for the average piece of land, the cost distributed over the whole irrigable area will be about $6 per acre, and that for the piece where 50% requires the concentrated expenditure (which must be considered a high percentage) the cost per acre in a similar way will only be about $8.

Since the classification has been completed, this study has been checked by actual results, and it has been found that the average

total cost per irrigable acre, including the $4 charge for smoothing and leveling, has been $5.70.

On 8%	of	the	farms	the	cost	was	less than $5.				
On 60%	"	"	"	"	"	"	between	$5	and	$6.
On 22%	"	"	"	"	"	"	"	6	"	7.
On 8½%	"	"	"	"	"	"	"	7	"	9.
On 1%	"	"	"	"	"	"	"	9	"	10.
On ½%	"	"	"	"	"	"	"	10	"	12.

Surveys and Plans Required.—It was realized that the basis of the very complete classification anticipated must be very accurate contour plans showing the detailed topography of all the area to be classified. The Canadian Pacific Railway Company was required to furnish the necessary plans, and as it had made topographical surveys covering only a small portion of the total area, it was necessary to make new surveys of the remainder.

The specifications for these plans were as follows:

1.—The scale of the plans shall be 400 ft. to 1 in.

2.—On every plan shall be shown 5-ft. contours in heavy lines, and wherever the slope is less than 2 ft. in 100 ft., 1-ft. contour lines shall be shown in thin lines.

3.—All "ring" contours in hollows or on summits shall be located on the ground by at least four points.

4.—All sloughs or other areas covered by water shall be located by at least four points.

5.—The tracings submitted in duplicate to the Commissioner of Irrigation shall be made from the original plane-table plans made in the field.

6.—The location and elevation of every field outlet shall be shown plainly on each plan. The elevation of the field outlet shall be a point 3 in. below the crest of the measuring weir, if located at or within the farm boundary; where this measuring weir is not at or within the farm boundary, the elevation of the field outlet shall be the elevation of full supply level in the lateral supplying such outlet.

7.—The area and location of such land as is commanded by the ditches, but which is plainly rendered non-irrigable owing to alkali or any other cause, shall be shown on the plans.

8.—No contour lines need be shown above the falling contour which passes through the elevation of the field outlet and falls from it at the following rates:

(*a*) Where the natural slope of the ground is less than 0.10 ft. in 100 ft., at a rate not less than 0.05 ft. in 100 ft.;

(*b*) Where the natural slope of the ground is greater than 0.10 ft. in 100 ft. at a rate not less than 0.10 ft. in 100 ft.;

(*c*) Where the natural slope of the ground is at or near the critical slope of 0.10 ft. in 100 ft. at either of the rates mentioned in (*a*) and (*b*), such as good and reasonable practice demands.

9.—Every precaution shall be taken to make the plans as accurate as possible within the limit of a reasonable expenditure of money. The maximum error in the plans area delineated by the critical contours shall not exceed $2\frac{1}{2}\%$ in any quarter-section of land.

10.—The exact location of any of the Company's distributaries or secondary canals which run through any parcel of land, shall be the outside lines which determine the land that is made non-tillable by the ditch construction or other works.

11.—All distinct drainage lines or channels shall be traced on the ground and shown on the plans.

12.—All plans submitted should be to a standard, over-all size, for the purpose of filing, and should not exceed 18 by 18 in. This will permit one section to be shown on each plan at a scale of 400 ft. to 1 in., and one quarter-section at a scale of 200 ft. to 1 in.

13.—It is understood that, under Secondary Canal *C*, about 90 000 acres of land have already been contoured to a scale of 1 000 ft. to 1 in. For this particular land, Paragraph 5 of these specifications shall be inoperative.

14.—It is understood that, under Secondary Canals *A*, *B*, and *C*, about 100 000 acres of land have already been surveyed to a scale of 200 ft. to 1 in. These surveys do not show contours, but show a classification of land, based particularly on soil conditions. These plans with descriptive notes will be accepted by the Commissioner of Irrigation, who will reserve the right to call for such additional information on any particular plan as he may require for the purpose of the re-classification.


R. of W. 0.07 Ac.
R/D. 0.29 Ac.
D-3222.8
D-3195.6
33.90 Ac.
116.30 Ac.
116.54 Ac.
R. of W. 9.2 Ac.
R. of W. 11.90 Ac.
31.80 Ac.
Wet Slough
Dec. 11, 1913
W.S.
D-3215.7
160.00 Ac.
160.00 Ac.
D-3190.5


R. W. 0.07 Ac.
R. D. 0.29 Ac.
D-3222.8
D-3195.6
C 15.8
A 36.1
E 5.1
B 33.9
33.90 Ac.
D 1.3
A 101.2
116.30 Ac.
C 10.3
116.54 Ac.
R. of W. 9.2 Ac.
R. of W. 11.9 Ac.
D 8.84
Wet Slough
Dec. 11, 1913
W.S.
F 0.7
B 31.8
31.80 Ac.
D-3215.7
C 16.8
116.00 Ac.
A 134.7
D 7.7
A 151.0
160.00 Ac.
Ditch through Irr. Area 1.0 Ac.
D.S.
B 0.3
E 1.3
D-3190.5
D 2.2
C 1.1
B 1.4
IRRIGABLE LAND
NON-IRRIGABLE LAND
Above point of delivery
Concentrated cost exceeds limit
Swamps, Alkali, Lake, Waterlogged
Slopes exceed limit
Otherwise undesirable for Irrigation
Ordinary Field Lateral projections

With reference to Clause 13 of the Specifications, this meant in practice that the plans submitted were to the general scale of 400 ft. to 1 in., but were enlarged from the original field plans (at 1 000 ft. to 1 in.) which had previously been prepared by the Company.

The left half of Plate XII shows a typical plan as submitted by the Company, and Fig. 2 shows a typical plan as submitted under the special Clause 14 of the Specifications.

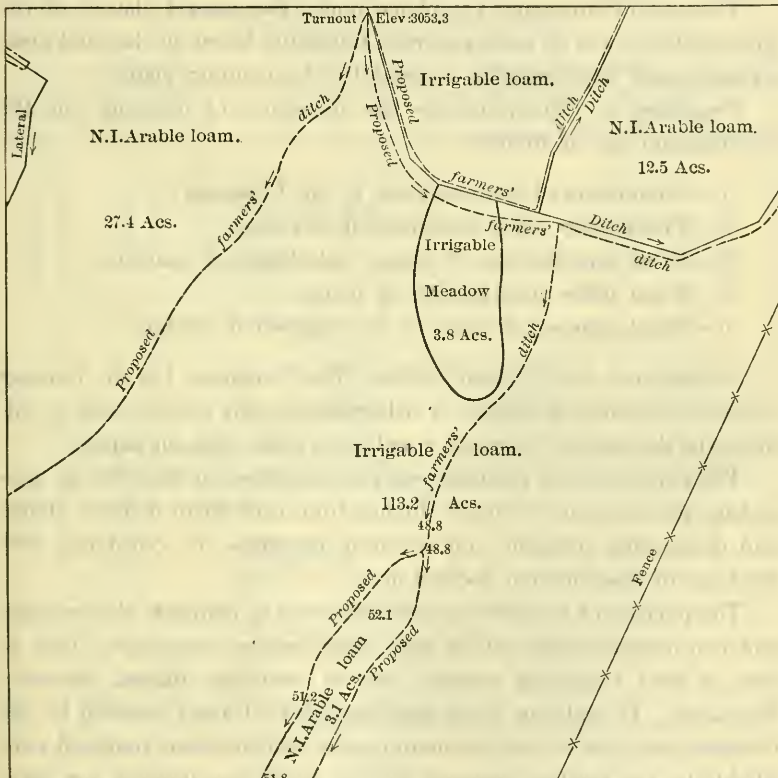


FIG. 2.

The Company has constructed all the canals and ditches which deliver the water to the field outlet for each parcel of land. The usual parcel to which a delivery is made is 160 acres, this being a legal quarter-section, the parcel usually dealt with in selling. In making the classification it was necessary to know the exact parcel of land that was to be served from any field outlet.

In the case of land already sold by the Company, agreements filed with the Department showed the parcels owned and included under each water agreement, and in these cases such areas were considered as one. In other special cases, usually concerning fractional areas, the Company's plans submitted showed by a conventional sign the special parcels that were to be sold together, and were so dealt with as regards parceling in the classification.

The cost of preparing the plans, under the general clauses of the Specifications, was 23 cents per acre, this being based on the total area, irrigable and non-irrigable, covered by the contour plans.

Procedure of Classification.—The procedure of carrying out the classification was as follows:

1.—Submission of contour plans by the Company;

2.—Preliminary office classification of plans;

3.—Field classification of plans, including soil analysis;

4.—Final office classification of plans;

5.—Final approval of plans by the engineer in charge.

Preliminary Office Classification.—The Canadian Pacific Railway Company operates at Calgary a lithographic print process, and, in addition to the original tracings, supplies an extra plan on paper.

The paper copy of the plan was then classified in the office by projecting the necessary farmers' ditches from each farm delivery shown and delineating irrigable and non-irrigable areas in accordance with the basis of classification decided upon.

The purpose of the office classification was to delineate the irrigable and non-irrigable areas which were dependent on topography, that is, cost of field irrigating ditches, cost of drainage ditches, excessive slopes, etc. In addition, there were excluded all areas reserved by the Company as right of way for main canals, and the areas rendered non-tillable by the smaller company laterals which ran through any farm and for which easement had been reserved in the land contract sale to the farmer.

The results of this office classification were scheduled on a "Land Classification Detail Sheet", Fig. 3, this sample referring to the right half of Plate XII.

The cost data for ditches, embankments, flumes, etc., used in the office classification were taken from the standard design sheets which

are shown as Figs. 4, 5, 6, and 7, which were worked up for office use from the basis of classification determined upon.

Field Classification.—The paper copies of the plans, together with the land classification detail sheet, were then sent out to the field, where, map in hand, the classification was carefully examined on the ground by the engineer in charge of the work. This engineer was supplied with a motor car for quickness of transport, and was assisted

LAND CLASSIFICATION DETAIL SHEET
WESTERN SECTION C.P.R.

S	T	R
8	23	25

OFFICE CLASSIFICATION				
CLASS. BY		CHECKED BY		APPROVED BY
A. A. S.	3/15	C. d.K.	9/81	R.C.S. OFFICE ENG.

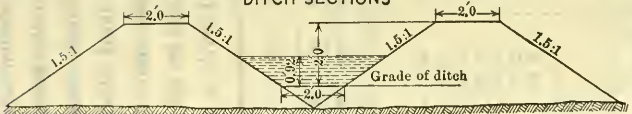
Parcel	N.W.¼
A	86.1 Ac. Irrigable
B	33.9 " N. I. Cost above limit.
C	15.8 " " " Above Delivery.
D	8.84 " " " Slough.
E	5.1 " " " Slopes.
F	0.7 " " " " "
	9.27 " " " Right of Way.
	0.29 " " " Road Right of Way
	Estimate
	50 Sta's @ $1.14 per Sta. $57.00
	18 " @ 1.25 " " 22.50
	24 " @ 1.18 " " 28.32
	$107.82
	TOTALS: Irr. 86.1 N.I. 64.34 Rt.-W. 9.56 Includes 0.29 Ac. Road Diversion
	Estimated Cost per acre of Ditches and Structures to Irrigate Land $1.25

Parcel	N.E.¼
A	104.2 Ac Irrigable.
B	31.8 " " "
C	10.3 " N I Slopes.
D	1.8 " " " Above Delivery.
	11.9 " " " Right of Way.
	Estimate
	24 Sta's @ $1.14 per Sta. $27.36
	52 @ 1.14 " " 59.28
	12 @ 1.20 " " 14.40
	$101.04
	TOTALS: Irr. 136.0 N.I. 12.1 Rt.-W. 11.9
	Estimated Cost per acre of Ditches and Structures to Irrigate Land $0.74

FIG. 3.

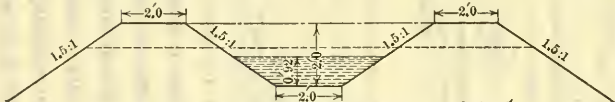
by three engineers, each accompanied by a rodman and a teamster with a democrat. The field work was most carefully examined, and, whenever any undesirable areas were found, such as alkali conditions, land not fit for cultivation, or any other conditions not shown by the contour plans, these areas were delineated by the level-compass-stadia method, and, where greater detail was necessary, by the plane-table. In many cases, also, of critical cost, an actual profile was run in the field for irrigation or drainage ditches, embankments, or flumes.

DITCH SECTIONS



FARM LATERAL
DOUBLE FILL

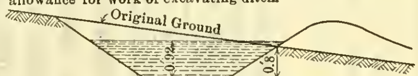
Use double fill when water level is from 0.3 to 1.7 above ground level.
Use fill as below when water level is more than 1.7 above ground, if less expensive than flume.



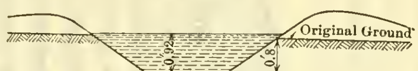
Hydraulic properties of Farm Lateral on Min: Grade 0.05%
$n = 0.025$ $s = 0.0005$ $Q = 2.46$ cu. ft. per sec.

FARM LATERAL
FILL

Fill to be constructed to the dotted line and the ditch excavated to the section shown. Cost data computed for fill to height of dot and dash line (top of Bank) to make allowance for work of excavating ditch.



FARM LATERAL
SIDE HILL SECTION



FARM LATERAL
LEVEL SECTION

COST OF FARM LATERAL

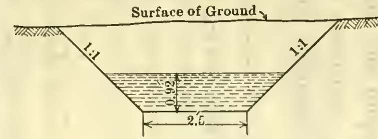
Cross Slope %	Cu. yds. per Sta. of 100′	Cost Dol's. per Sta.
0	9.46	1.14
1	9.84	1.16
2	10.20	1.22
3	10.61	1.27
4	11.00	1.32
5	11.40	1.37
6	11.80	1.42
7	12.25	1.47
8	12.75	1.53
9	13.20	1.58
10	13.70	1.61
11	14.22	1.71
12	14.73	1.76
13	15.30	1.83
14	15.83	1.90
15	16.40	1.97
17½	17.95	2.15
20	19.70	2.26
For Laterals up to 2.5% Max: Grade		

COST OF DOUBLE FILL

Height-Ground to water level	Cu. yds. per Sta +15% Shrinkage	Cost per 100′ @12¢ p.cu.yd.
0.0	29.6	3.58
0.5	54.3	6.52
1.0	85.0	10.20
1.5	122.4	14.70
2.0	210.4	25.20
2.5	257.0	30.85
3.0	306.0	37.48
3.5	358.6	43.05
4.0	415.0	49.80
4.5	472.8	56.70
5.0	536.0	64.30
5.5	601.0	72.12
6.0	670.0	80.40
6.5	742.0	89.05
7.0	816.0	97.90
7.5	894.0	107.40
8.0	977.0	117.25
8.5	1061.0	127.35

COST OF FARM LATERALS ON A GRADE BETWEEN 2.5% & 5.5%

% Grade	Dollars per 100 ft.	Number of Drops
2.5	1.14	0
3.0	5.42	1
4.0	9.70	2
5.0	13.98	3
For Ditches exceeding 5.5% Grade use a Chute		

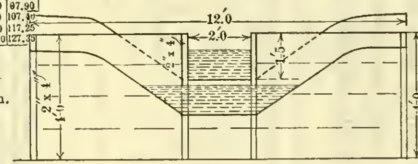


FARM LATERAL
THROUGH CUT

CROSS-SECTION WHERE THE CUT EXCEEDS 1.0

THROUGH CUT

Depth of Grade	Cu. yds. per Station	Cost per Sta. @12¢ p.cu.yd.
1.0	13.0	1.55
1.5	22.2	2.65
2.0	33.3	4.00
2.5	46.3	5.55
3.0	61.1	7.35
3.5	77.7	9.35
4.0	96.2	11.55
4.5	116.5	14.00
5.0	139.0	16.70
5.5	163.0	19.55
6.0	189.0	22.70
6.5	217.0	26.05
7.0	247.0	29.65



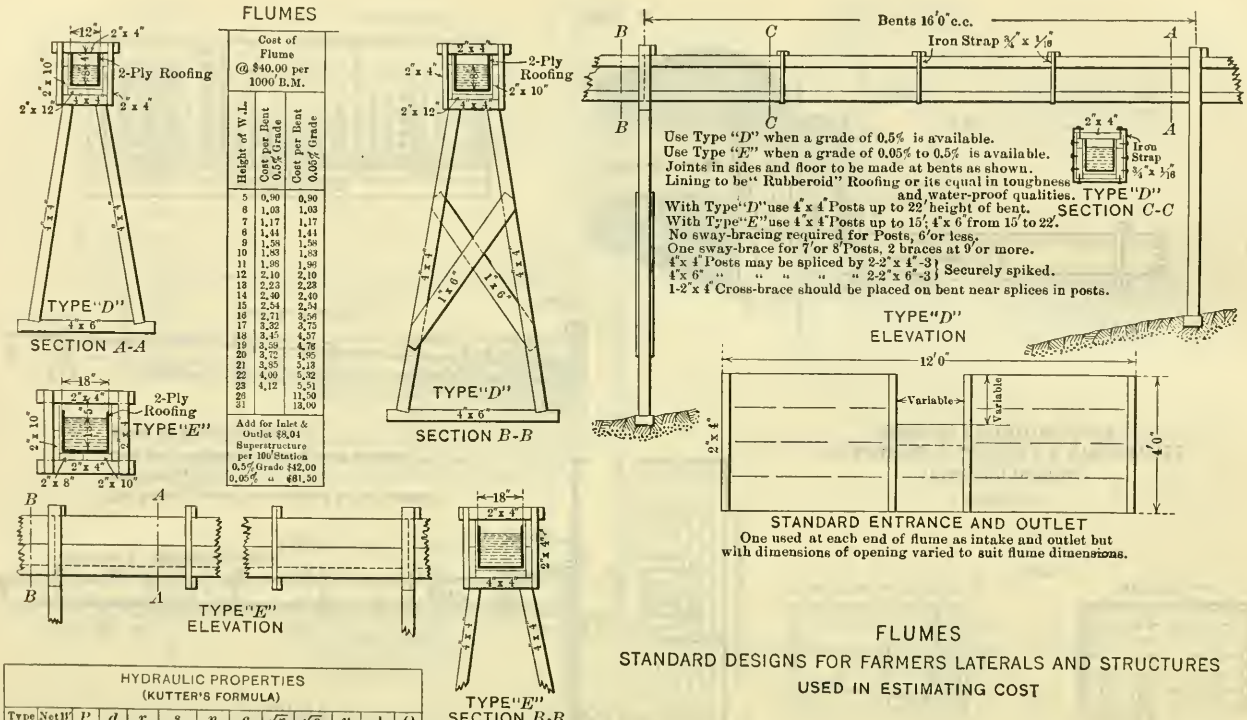
STANDARD ONE-FOOT DROP

BILL OF MATERIAL

P'cs	Size	Lgth.	F.B.M.
1	2″x4″	16′	11
4	2″x12″	12′	96
			107.

DITCH SECTIONS
STANDARD DESIGNS FOR FARMERS LATERALS & STRUCTURES
USED IN ESTIMATING COST

FIG. 4.



FLUMES

Height of W.L.	Cost per Bent 0.5% Grade	Cost per Bent 0.05% Grade
5	0.90	0.90
6	1.03	1.03
7	1.17	1.17
8	1.44	1.44
9	1.58	1.58
10	1.83	1.83
11	1.98	1.96
12	2.10	2.10
13	2.23	2.23
14	2.40	2.40
15	2.54	2.54
16	2.71	3.56
17	3.32	3.75
18	3.45	4.57
19	3.59	4.76
20	3.72	4.95
21	3.85	5.13
22	4.00	5.32
23	4.12	5.51
26		11.50
31		13.00

Cost of Flume @ $40.00 per 1000' B.M.

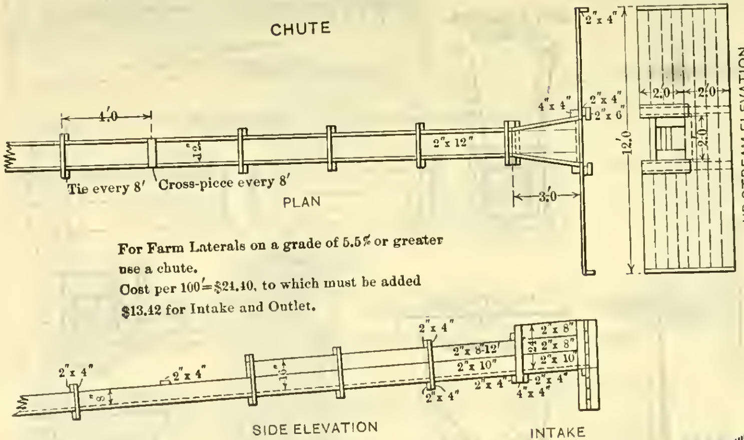
Add for Inlet & Outlet $8.04
Superstructure per 100' Station
0.5% Grade $42.00
0.05% " $61.50

HYDRAULIC PROPERTIES
(KUTTER'S FORMULA)

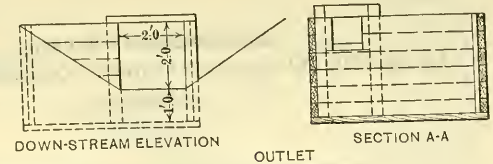
Type	Net W	P	d	r	s	n	c	$\sqrt{r}$	$\sqrt{s}$	v	A	Q
D	0.96	2.36	0.70	0.284	0.005	0.010	124.2	0.533	0.071	4.68	0.672	3.14
E	1.44	3.64	1.10	0.435	0.0005	0.010	133.2	0.660	0.0224	1.97	158.4	3.12

FLUMES
STANDARD DESIGNS FOR FARMERS LATERALS AND STRUCTURES
USED IN ESTIMATING COST

FIG. 5.



For Farm Laterals on a grade of 5.5% or greater use a chute.
Cost per 100' = $21.40, to which must be added $13.42 for Intake and Outlet.



CHUTES
STANDARD DESIGNS
FOR FARMERS LATERALS & STRUCTURES
USED IN ESTIMITING COST

BILL OF MATERIAL

Intake				16' of Box				Outlet			
Pc's.	Size	Lgt'h	F.B.M.	Pc's.	Size	Lgt'h	F.B.M.	Pc's.	Size	Lgt'h	F.B.M.
1	4 x 4	14	19	1	2 x 12	16	32	1	4 x 4	9	12
1	2 x 12	16	32	2	2 x 16	16	53	1	2 x 12	18	36
2	2 x 12	12	48	1	2 x 4	18	12	2	2 x 12	16	64
2	2 x 12	10	40				97	1	2 x 12	12	24
2	2 x 10	16	53					1	2 x 4	12	8
3	2 x 8	12	48								144
1	2 x 6	10	10								
3	2 x 4	16	32								
			282								

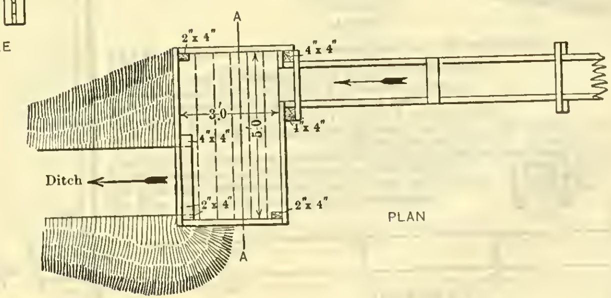


FIG. 6.

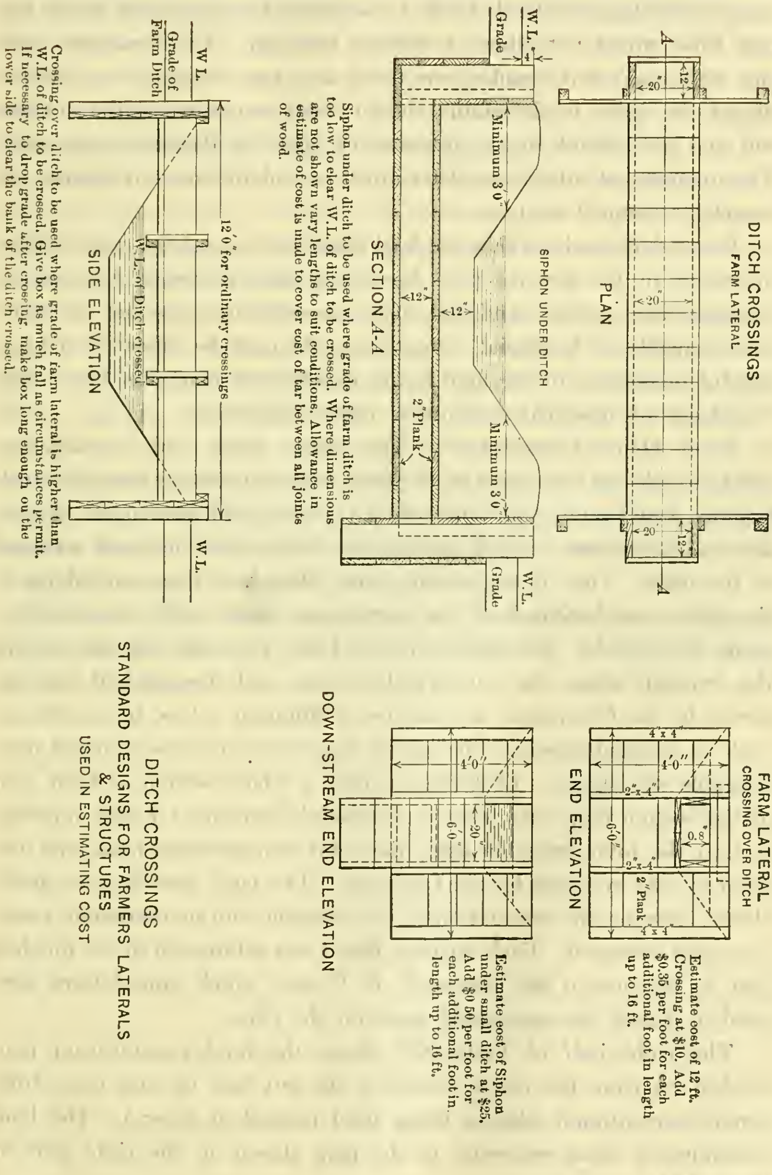

DITCH CROSSINGS
FARM LATERAL
PLAN
SIPHON UNDER DITCH
Minimum 3'0"
2" Plank
W.L.
Grade
SECTION A-A
Siphon under ditch to be used where grade of farm ditch is too low to clear W.L. of ditch to be crossed. Where dimensions are not shown vary lengths to suit conditions. Allowance in estimate of cost is made to cover cost of tar between all joints of wood.
12'0" for ordinary crossings
W.L. of Ditch crossed
Grade of Farm Ditch
SIDE ELEVATION
Crossing over ditch to be used where grade of farm lateral is higher than W.L. of ditch to be crossed. Give box as much fall as circumstances permit. If necessary to drop grade after crossing, make box long enough on the lower side to clear the bank of the ditch crossed.
FARM LATERAL
CROSSING OVER DITCH
END ELEVATION
2" Plank
Estimate cost of 12 ft. Crossing at $10. Add $0.35 per foot for each additional foot in length up to 16 ft.
DOWN-STREAM END ELEVATION
Estimate cost of Siphon under small ditch at $25. Add $0 50 per foot for each additional foot in length up to 16 ft.
DITCH CROSSINGS
STANDARD DESIGNS FOR FARMERS LATERALS & STRUCTURES
USED IN ESTIMATING COST

FIG. 7.

One of the most difficult features was the determination of unsuitable soil conditions and the greatest care was exercised in excluding alkalied lands or lands likely to be alkalied by irrigation where the cost limit would not allow of efficient drainage. In connection with this work many soil samples were taken with the soil auger or post-hole digger, in order to determine the physical structure of the surface soil and the subsoil, or the presence of alkali in dangerous quantity. The quantity of alkali was determined by submitting soil samples to complete chemical analysis.

It was fully realized that the field classification was the most critical operation in the general procedure, and that, following the careful topographical surveys and the office classification, the net irrigable areas capable of beneficial irrigation could only be determined by a careful inspection in the field by an experienced man who had a full knowledge of practical agriculture under irrigation.

Final Office Classification.—The paper plans and classification sheets which had been used in the field were returned to the office with copious pencil notes and, where field traverses had been made or profiles run, these were plotted on separate sheets in the field and attached to the plans. One of the tracing linen plans was then worked up in the office, and included all the corrections to the office classification made in the field. The scheme adopted was to outline on the tracing the irrigable areas, the non-irrigable areas, and the right of way reserved by the Company. By the use of different colors, in accordance with an adopted schedule, the reason that each area was rendered non-irrigable was shown. Each plan showed a whole section of land, and at the bottom there was filled in a schedule showing for each quarter-section the total irrigable land, the total non-irrigable land, and the right of way reserved by the Company. The land classification detail sheets, showing the summation of the irrigable and non-irrigable areas, were also corrected. Each separate detail was referenced to the finished plan by the use of the letters, *A, B, C,* etc., which same letters were used to denote the segregated areas on the plan.

The right half of Plate XII shows the final classification plan worked up from the plans shown on the left half of that plate (different conventional edgings being used instead of colors). The land classification sheet referring to the plan shown on the right half of Plate XII is also shown.

With the special plans submitted under Clause 14 of the Specifications, the result obtained was practically the same, but the procedure was necessarily somewhat different. These plans showed the result of a classification in the field by the Company's officials, who had worked under instructions which were practically the same as the basis of classification adopted. No contour lines being shown on these plans, no preliminary office classification was possible, and all the checking had to be done in the field, which necessitated considerable more work in determining elevations and delineating areas by the field assistants. The final classification plan was prepared in the same manner as described above.

Final Approval of Plans and Classification.—The final approval was made by the engineer in charge after checking the plans to see that the field notes submitted had been properly interpreted in the office in making up the final copy. The cost of making the classification based on the total area inspected was 16.2 cents per acre, of which 7 cents is chargeable to office work. Based on the irrigable acreage only, the cost was 32.9 cents per acre with 14.1 cents chargeable to office work. These costs included making duplicates of all the classification maps for special purposes of record.

Personnel.—The work was carried out under the direct charge of G. N. Houston, M. Am. Soc. C. E., and Mr. R. C. Spitzer acted as Office Engineer.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PRESERVATION OF SANDY BEACHES IN THE VICINITY OF NEW YORK CITY

Discussion.*

By A. W. Buel, M. Am. Soc. C. E.

A. W. Buel,† M. Am. Soc. C. E.—In his discussion, Mr. Schwiers has referred to the Case system of groynes which has been used with great success in several places in England, on both the south and east coasts. These groynes are very low, sometimes only a few inches above the beach, and never more than 18 in. They are arranged so that, as the beach is built up by catching the littoral drift, additional planks can be put in, the groynes thus being raised from season to season. There are records of some places on the English coast where the beach has been built up as much as 8 ft. in a few seasons, and extended out several hundred feet. Mr. Buel.

Mr. Case almost invariably had a very low wall at the top of his groynes, that is, at the shore line above high water, and, generally, he used a pavement connecting the beach or the groynes with the sea-wall which he made elliptical. He adopted the elliptical curve as that most nearly agreeing with the angle of repose on the beach under the conditions that exist in those parts of England.

Mr. Allanson-Winn has written several papers‡ in which he describes the results obtained with Case groynes, and suggests an addition or improvement to the system, consisting of what amounts to extensions of the groynes to a connection with the sea-wall or bulkhead. This extension, from high-water line to bulkhead, is curved in plan. On all the beaches along the New Jersey coast, and also

* Discussion of the paper by Elliott J. Dent, M. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† New York City.

‡ *Minutes of Proceedings*, Inst. C. E.

Mr. Buel. on Long Island, the jetties or groynes are what would be described as high groynes, when compared with the Case system. They are far more substantial and expensive structures than those described by Mr. Case and Mr. Allanson-Winn and, for this reason, are probably less efficient. The very low Case groyne builds up a smoother, more uniform beach than the jetties used on the Jersey and Long Island shores.

The Case groynes were built in England at a cost of about 10 shillings per lin. ft., and Mr. Allanson-Winn's curved extension, connecting the groynes with the bulkhead wall, does not cost more than £1 per lin. ft.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

THE PROPERTIES OF BALSA WOOD

(*Ochroma Lagopus*)

Discussion.*

By Leonard M. Cox, M. Am. Soc. C. E.

Leonard M. Cox,† M. Am. Soc. C. E.—Although he can add nothing of professional value to the discussion of this excellent paper, the speaker feels a curious interest in the insulating properties of balsa wood. Some 15 years ago, it was his fortune to serve as Chief of Public Works at the Island of Guam, and among a number of more or less serious problems which confronted the pioneers of that day, was one which was never solved in an entirely satisfactory manner with the materials available. The cold storage room of the miniature ice plant served fairly well for caribou and American beef, but invariably caused the loss of fully half the mutton and poultry begged from the army transports on their monthly visits. From a first reading of the paper, it seemed at least possible that a very common Guam tree was akin to, if not identical with, the balsa tree, and that the remedy for our cold storage troubles had been near at hand though unrecognized. Personal notes consulted since the presentation of the paper before the Society establish the fact that the Guam tree, known locally as pago (*Hibiscus tiliaceus*), bears slight resemblance to the balsa tree, except as regards its comparative lightness and structure, as indicated by cut surfaces. Its weight per cubic foot is 24 lb.; it has considerable bending strength; is of about the color of Flemish oak; and rarely grows to a size exceeding 6 in. in diameter. Mr. Cox.

The reference in the paper to the Marr wood-preserving process also interests the speaker for the reason that while he was on duty at the Norfolk Navy Yard in April, 1914, a number of experimental

* Discussion of the paper by R. C. Carpenter, M. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† Brooklyn, N. Y.

Mr. Cox. timbers, running from 8 by 8 in. to 10 by 10 in., were impregnated with the Marr paraffin, in which there was incorporated finely divided silica. These pieces were suspended half in water and half in air, beneath one of the Yard wharves. At the same time six pieces, 4 by 6 in. and 4 by 4 in., were impregnated with the paraffin without silica, and buried to half their lengths in the ground. These test pieces were examined on July 15th, 1915, and found to be in excellent condition. They have also been examined during the latter part of June, 1916, and show no evidences of deterioration. The specimens which had been placed in water had a small quantity of shells and vegetable growth attached to their surfaces, all of which promptly fell off when the timbers were struck. On cutting into the wood, it was found that the interior was perfectly bright, and exhibited the distinctive red color of the process. The pieces in the ground show no signs of rot or age. Of course, tests on such a small scale cannot be considered determinative, and it is hoped that other engineers will give the Profession the benefit of any experience they may have had with this process.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

CONTROL OF THE COLORADO RIVER AS RELATED TO THE PROTECTION OF IMPERIAL VALLEY

Discussion.*

By Messrs. A. L. Sonderegger and J. A. Ockerson.

A. L. Sonderegger,† M. Am. Soc. C. E. (by letter).‡—There are three engineering problems which to-day confront the Imperial Valley Irrigation District and are more or less related to each other: First, the protection from overflow of the Colorado River; second, the silt problem; third, the problem of diverting the low-water flow of the river during the latter part of the summer, when the greater portion, or all, of the flow of the Colorado River is required for irrigation in the valley. Mr. Sonderegger.

Mr. Allison presents a simple and practicable solution of the first problem. The efficiency of the proposed system of defense can hardly be questioned, as it has already had its practical test, at least in part. The plan includes three main lines of defense.

First line: The diversion of the Colorado River into its old channel along the Arizona and Sonora Mesa; the closure of the breach of the Ockerson levee at the head of the Bee River, together with the restoration of the Ockerson levee, or a new levee similarly situated.

Second line: The westerly portion of the C. D. levee and its prolongation, called the Paredones or Holabird levee, and to the west thereof the Volcano Lake levee.

* This discussion (of the paper by J. C. Allison, Assoc. M. Am. Soc. C. E., published in May, 1916, *Proceedings*, and presented at the meeting of September 6th, 1916), is printed in *Proceedings*, in order that the views expressed may be brought before all members for further discussion.

† Los Angeles, Cal.

‡ Received by the Secretary, August 30th, 1916.

Mr. Sondereg-ger. Third line: The embankment of the Inter-California Railroad as far west as the Alamo-Mocho Canal, and a new proposed levee along this canal and westerly thereof to the West Side Main Canal just south of Calexico.

Of the first line of defense, the upper part of the old C. D. levee, from Hanlon Heading to its junction with the Ockerson levee, has withstood successfully the undermining of the river, wherever rip-rapped with rock. The break in the levee at "House 7", which occurred in 1914, was due to lack of maintenance. Nevertheless, this first section of levee forms the weakest portion of the whole system of defense.

Mr. Allison has referred to the undermining of the foundations of the old concrete piers built on the granite ledge at the Hanlon head-gate. The writer is quite familiar with these foundations, as the new Stoney gate was put in, during the winter of 1913-14, under his direction as Consulting Engineer for Mr. W. H. Holabird as Receiver. It developed that the granite ledge was a shattered mass of soft rock with many seams of disintegrated granite and strata resembling talcum, sometimes several feet in thickness. There was no need of any blasting, all excavation being made with pick and shovel. The foundations uncovered under the old piers within the temporary coffer-dam were badly undermined. In one instance there was a cavity under the down-stream side of a pier large enough to accommodate an office desk. The 8-in. concrete floor-slab was broken off and eroded in many places. Soundings along the remaining piers showed that they also were badly undermined, although calculations regarding their stability revealed a small margin of safety. Lack of funds prevented the Receiver from repairing the foundations of these piers, and they still constitute a danger which should be eliminated. A granite quarry is within 1 000 ft. of the heading, and, in case of a break, rock could be dumped without delay.

From the heading down to the junction of the Ockerson levee there is only a single line of defense. This section of the levee has already been revetted for some distance. If the levee is watched, no danger need develop, as it carries a standard track, and rock can be dumped at short notice wherever the current approaches the levee. Some of the revetments were lost in January, 1916, owing to absence of maintenance.

Regarding the location of the Ockerson levee, the writer agrees that, as far as river control is concerned, it is of vital importance to concentrate the flow of the river, and to prevent meandering between levees.

As regards the proposed method of closure of the Bee River by a temporary diversion of the Colorado River at Hanlon Heading during the low-water stage, two facts seem to stand out very clearly: first,

Mr. Sonderegger.

that the construction of a hydraulic-fill dam can be accomplished successfully; and second, that it can be done at very low expense.

The difficult part of this work—the closure of the last gap in the dam—was effected successfully, not only once, but several times, when it became necessary to cut the dam for the passage of temporary floods; therefore, there can be no doubt as to the success of any future operation of this kind. Both the method and the low cost bear witness to the ingenuity and resourcefulness of the directing engineer.

Considerable dredging will be necessary in the old channel below the Bee River Heading before the river can be diverted permanently. It is probable that the work will extend over a period of 2 or 3 years before a channel can be secured capable of accommodating the winter flow and occasional freshets as they occur; but, unless there are high waters of an extreme nature, and out of season, the writer believes that the diversion can be effected without any great risk.

The second line of defense—the C. D. levee, together with the Holabird and Volcano Lake levees—had proved its efficiency for several years, until in 1914, in the absence of maintenance, a break occurred. The difficulties encountered in the attempt to close the breach indicated clearly the necessity of establishing permanent connection by rail to the Hanlon Quarry. This was done in 1916. This Volcano Lake levee to-day presents the only protection for the valley. It is partly revetted with rock.

The third line of defense, especially the proposed levee along the Alamo-Mocho Canal, and westward therefrom, also had a partial test during the break in the Volcano Lake levee of 1914. At that time the bank of the Alamo-Mocho Canal intercepted the floods issuing from Volcano Lake, causing them to spread out in a thin sheet over the country to the south and west thereof. This canal crosses the New River channel on a solid embankment, and although it ends about 5 miles to the west thereof, it effectively prevented a concentration of flood waters for several days. The water finally found its way around the end of the canal bank into New River. The levee proposed by Mr. Allison would perfect the existing system of protection.

During the summer of 1916 a new canal was built from the west end of Volcano Lake levee, in a northerly and northwesterly direction, to the intersection of the Wistaria Canal with the West Side Main Canal. This point is about $3\frac{1}{2}$ miles south of Calexico. This canal forms the first side of a triangle, of which the Volcano Lake levee and its extension to the Inter-California Railroad forms the second side, and the railroad levee and the Alamo-Mocho Canal, with its proposed westerly prolongation, the third side. The area over which a flood from Volcano Lake might be spread has been reduced by the construction of this new canal, and a deflection of flood waters to the west is made impossible, unless the new canal is cut. The

Mr. Sondereg-ger. lowest point of the triangle is at Wistaria Heading. The levee proposed by Mr. Allison, and running from the Alamo-Mocho Canal westward, is still a necessity, in order to close the third side of this triangle and thereby make the third line of defense fully effective.

The question naturally arises as to the effect, on the grade of the river, of the proposed diversion of the Colorado into its old channel: Eventually, it would affect both the levee protection work of the Yuma Project and the diversion into the Alamo Canal of the low-water flow of the river.

From the reports of Col. Ockerson and Mr. Randolph it must be inferred that in 1911 the slope from the head of the Bee River to Volcano Lake was about 2.2 ft. per mile, while along the old channel of the river it was 1.08 ft. per mile. Since 1911 enormous deposits of silt have been carried into the depression of Volcano Lake, so that the grade to the lake has probably decreased. However, there must still be a preponderance of grade in that direction.

It is a fact that the diversion into the lake did cause a recession of grade extending at least as far up as Yuma, and this fact has undoubtedly contributed to the difficulty of diverting the low-water flow into the Alamo Canal. The trouble has become very acute, not only in the case of extreme low waters, as in 1915 when the river fell to a discharge of 3 000 sec-ft., but also with moderate volumes, as in 1916, when a water shortage occurred in the valley, with a low-water average of 25 000 sec-ft.

It is to be expected that the restoration of the old channel will cause a raising of the river bed, especially at low-water stages. On the other hand, the confining of the flow between the Arizona Mesa and the levee on the west side may cause a concentration of flow at high-water stages, and, simultaneously therewith, a scouring.

Since low waters occur during August, the question of securing a sufficient supply for the valley is second in importance only to the question of defense. It is, furthermore, intimately related to the silt problem, and the two questions will be discussed together.

While in the employ of the Receiver of the California Development Company, the writer, in conjunction with Mr. Allison, made extensive studies regarding the phenomena which affect the diversion of the river at Hanlon Heading.

It should be remembered that the granite ledge which carries Hanlon Heading, is not on the banks of the river, but approximately 2 000 ft. below them. The sills of the old gates are at an elevation of 98 ft., and of the new Stoney gate, at 93; and the low-water stage of the river, of late years, has never fallen below an elevation of 104.3 ft. Theoretically, there has been sufficient fall to effect a diversion, especially since the erection of the Stoney gate in 1914. At the intake of the canal, water is diverted at an angle of 90°, which naturally

causes a decrease in velocity from that along the axis of the river. The result is the formation of a bar at the intake. Mr. Sonderegger.

During high waters this first section of 2 000 ft. of canal above the gate operates as a settling basin. It is about 100 ft. wide, and varies in depth from 3 to 15 ft. With a rising river, the bottom of the canal rises practically at the same time as the water level of the river, causing a silting up of the canal to a depth of 10 ft. or more. Apparently, the cross-section of the canal and the velocity of the water are regulated automatically, corresponding to the volume diverted and the quantity of silt carried by the river. The swift currents carry heavy silt, shingle, and driftwood, large quantities of which are diverted into the canal, having a tendency to pile up in front of the head-gate. Desirable as it might be to prevent the admission of these silt-laden waters, yet the present position of the head-gate makes it necessary to keep its sill clear, so as to prevent the formation of mud banks and log jams immediately above the sill. Once such a bank is formed, it cannot be flushed out, and, with a sudden drop in the river, the heading might be left high and dry. The practice adopted by English engineers with Indian canals—providing gates with two or three leaves, which enable them, during high water, to skim the water off the top—cannot be adopted for the Alamo heading with the head-gate in its present location.

Immediately below the heading the canal enlarges to a bowl shape with a width of about 200 ft. Here the waters, rushing through the gate, are stilled, and drop their heaviest detritus, the effect being that a bar is formed a few hundred feet below the heading. The width of this bar varies from 1 000 to 2 000 ft. During the high water of 1914, this bar reached an elevation of from 102 to 103 ft.

High waters generally occur in June and July, after which the river drops suddenly. Experience has shown that, if the sill is kept clear, the section of the canal above the gate is scoured practically simultaneously with the drop of the water level of the river, leaving, however, a bar at the entrance. To dispose of this the 10-in. suction dredge *El Centro* is used, and no difficulty has been experienced in keeping the channel open.

Below the gate, however, the bar is not scoured out by a falling river; in such a case, the grade of the intake canal is governed by the water surface in the river, and the elevation of this bar is independent of the elevation of the sills of the gate. In fact, the maximum elevation of the bar has been from 4 to 5 ft. higher than the sills of the old miter gates, and from 9 to 10 ft. higher than the sills of the Stoney gate. The only means of eliminating this bar has been the operation of the 15-in. suction-dredge *Imperial*. In 1914 the bar was reduced to an elevation of 99 ft., sufficient to divert the necessary low-water

Mr. Sonderegger. flow; but in 1915 and 1916 it has required the raising of the water level in the river by temporary dams.

The situation, therefore, is as follows: During high waters large quantities of heavy silt and shingle enter the canal, forming a bar below the head-gate, the elevation of which depends mainly on the high-water conditions of the river. With a drop in the river, its velocities decrease, and the volume of silt carried is reduced correspondingly. The canal then begins to scour in the section above the gate, lowering the bottom automatically. If the drop in the river is not too sudden, this scouring keeps pace with the lowering of the water surface, however, leaving a bar at the intake; but, below the gate, apparently no scouring action occurs, and it requires the operation of a dredge to reduce the lower bar, or the construction of a dam to raise the water level in the river.

In view of these facts, the immediate effect of the restoration of the old channel of the river on the elevation of the low-water level at Hanlon, and the problem of diverting the low-water flow, cannot be predicted with certainty. Undoubtedly, in time, it would be beneficial; but how soon the effect would be noticeable, and whether it would be sufficient to eliminate the present difficulty completely, are still open questions. In solving the problem, the most important feature is to prevent the heavy silt, which rolls along the river bottom, from entering the canal; especially at high-water stages, only the surface waters of the river should be admitted.

This can be accomplished by constructing head-works along the banks of the river at a point where the current will strike the gate permanently and keep the sill clear.

It is generally admitted that the construction of a permanent dam near Hanlon Heading is excluded, for many obvious reasons. The writer agrees with Mr. Allison that it is not advisable to construct a new heading on the banks of the river on an alluvial silt foundation, even if provided with a rock-fill foundation and extensive rock-fill aprons. This would probably be the method of construction to be adopted if a gate were placed, as has been suggested, at the site of the well-known break of 1906 which was closed by a rock-fill embankment. It is difficult, if not impossible, to estimate the extent of the boring action which will take place in front of a gate during an extreme high water. Undoubtedly, the action is quite different from that occurring along a revetted bank. Provision would have to be made for the maintenance of the rock fill, by a system of tracks commanding the entire up-stream apron and its wings. In order to avoid excessive vibration and a slow wreckage from such forces, an extremely massive concrete floor under the gate proper would have to be provided. At least, a gate in such a location would require unceasing vigil, and present a constant menace to the valley.

However, a location which is worthy of investigation exists on the west bank about 1½ miles above Hanlon Heading, and the writer is informed that this locality is now under consideration by the Imperial Irrigation District. Mr. Sonderegger.

The bank at that point is on the convex side of the river, and is swept by the main current during the greater part of the year. It consists of a ledge of conglomerate which apparently presents some resistance to the boring and scouring action of the river. It will require careful soundings and investigation before its suitability can be determined definitely.

If the result should be found to be satisfactory, a heading can be constructed in a manner that will prevent heavy silt from entering the canal. The writer believes that even in the absence of special settling basins, the quantity of silt admitted to the canal can be reduced materially, and that this would produce the effect of scouring in the Alamo Canal. The present grade of this canal is practically stationary, and is the result of the discharge of waters carrying extremely high percentages of silt and sand. If operated under the same grade, but with comparatively clear water, a scouring action is sure to occur. It is a phenomenon often observed in the canals in Imperial Valley.

Probably, as far as the average low-water discharge is concerned, there would be no difficulty in diverting the quantity necessary for irrigation; for extreme low waters, as they have occurred in 1912, 1913, 1914, and 1915, when at times practically the entire flow was diverted, there would still be the necessity for the construction of temporary dams—whether they are hydraulic-fill or rock-fill. It should be remembered that increasing quantities of water will be diverted for the Yuma Project as all its lands are brought under cultivation. Similarly, there is still a constant increase in the acreage in Imperial Valley, so that within a few years the entire low-water flow of the river will be required. This is exemplified in the report* by E. C. LaRue, Assoc. M. Am. Soc. C. E.

It may be stated, therefore, that the reconstruction of the heading on the banks of the river, 1½ miles above Hanlon, even if found practicable, will present but a partial solution of the problem of diverting the low-water flow, and, likewise, only a partial solution as regards the elimination of silt, provided the river maintains its present channel. The successful removal of all silt by settling basins—in the opinion of the writer—depends entirely on the operation of the proposed new heading.

Another plan for securing a sufficient supply of clear water for Imperial Valley is the proposed construction of a canal from Hanlon Heading to Laguna Dam. There will be no engineering difficulties

* *Water-Supply Paper No. 395.*

Mr. Sonderegger. in the construction of the connecting canal. The proposed route crosses several large washes which, at long intervals, are subject to sudden floods resulting from cloudbursts. However, there is sufficient grade available, so that short portions of the canal can be constructed as underground conduits with heavy grades and correspondingly reduced cross-sections, thus, the cost of construction is not likely to be excessive.

There is one feature of this plan which will require careful consideration, namely, the necessity of the continuous operation of the Imperial Canals. The Laguna Project at present diverts probably not in excess of 750 sec-ft. during the summer. In order to have the benefit of the settling basin above the dam, it is necessary to flush the settling pond immediately above the intake one day per week, so that the canals are operated 6 days out of the 7. The distance from Laguna Dam to Yuma is about 12 miles.

It is doubtful whether this mode of operation could be applied to the Imperial system. The summer diversions would be increased from 750 to about 6 000 sec-ft., and, during the low stages of the river, every drop would be diverted. The distance from Laguna Dam to Imperial Valley is about 75 miles, and, in view of this, it is doubtful whether intermittent operation would be successful. In other words, though the connection with the Laguna Dam would undoubtedly secure a permanent supply, it would not solve the silt problem completely.

Whatever solution will finally be chosen, it will necessitate the expenditure of large sums of money, and on the success of the undertaking will depend the future of Imperial Valley. No decision should be made, therefore, except after full and mature consideration of all questions involved.

Mr. Ockerson. J. A. OCKERSON,* PAST-PRESIDENT, AM. SOC. C. E. (by letter).†—In this paper, Mr. Allison presents some very interesting and novel features. His long experience in connection with the irrigation of Imperial Valley gives exceptional weight to his views as to the proper solution of the vexing problems involved.

Complicated by International Boundary Line.—A comprehensive plan for the reclamation of the Colorado River delta is complicated by the presence of the International Boundary Line between the United States and Mexico.

If that was eliminated, the restoration of the river to its former bed and the limitation of its floods thereto by suitable levees or embankments, together with such revetment as might be necessary to check and prevent excessive bank erosion, would solve the problem of regulation definitely, so far as the river itself is concerned. "Interior

* St. Louis, Mo.

† Received by the Secretary, September 1st, 1916.

lines of defense", which, at best, are temporary makeshifts, would then be unnecessary. Mr. Ockerson.

The water of the river, however, is necessary to supply moisture to about 500 000 acres in Imperial Valley, California, and about double that area on the Mexican side of the line. This is more than double the total area of land reclaimed by the United States Reclamation Service, and Imperial Valley alone has a cultivated area measuring more than two-thirds of the total of all the Reclamation projects. This gives a fair measure of the importance of the projects under discussion.

It is the diversion, control, and distribution of this water in Imperial Valley which has largely claimed Mr. Allison's attention for several years, the development of the Mexican side being comparatively small.

The New River Gorge.—The development of the New River gorge is commonly attributed to the break of 1905, when the Colorado River left its channel and emptied its waters into Salton Sea. An investigation of the earliest records left by the stream itself in its wanderings shows plainly that this diversion to the Salton Sea had occurred many times in the distant past.

Early Mexican maps, dating back to a time before any attempt had been made to divert and control the waters, show the New River gorge to have been developed to a considerable extent even then. The rapid enlargement of the gorge during 1905-06 was most impressive as an example of excavation on a gigantic scale, such as would make the Panama Canal work seem insignificant, and has rarely been equalled elsewhere in nature.*

Break in the Levee at "House 7".—The author speaks of the breach in the levee at "House 7", and suggests that the use of "jetties" to deflect the current away from the bank would have prevented the damage until rock revetment could have been applied. He also states that there was "no danger of destructive flooding, as the river did not overflow the banks". If the records of the Reclamation Service are correct, the river banks at the point named have never been overflowed by the highest known floods, and why "the simple expedient of building a levee around the break", or why a levee 9 ft. high was ever built at all on a bank which is 4 ft. above the highest known flood, has always been a mystery to the writer. It is fair to say that the author was not responsible for either of these.

Deflecting Dikes or Jetties.—The use of dikes or jetties to deflect the current away from the banks is a common delusion. R. Jasmund, in his review of the regulation of the Rhine, covering some 150 years, recites the "countless failures" in which deflecting dikes had a very large share. He says that, in spite of such dikes inclining down stream,

* *Transactions,* Am. Soc. C. E., Vol. LIX, Plates V and VI, and p. 37.

Mr. Ockerson. the bank receded more and more and, in many cases, the erosion was strongest just behind the dikes, where protection had been looked for, and the dikes themselves were cut out and disappeared. After being thoroughly tried out, the deflecting type of dike was abandoned, and dikes of suitable length perpendicular to the bank were substituted, which resulted in deposits along the shore below them, and this method has had a large part in the successful regulation of the Rhine and other streams.

Like experience on the Mississippi and Missouri Rivers has also demonstrated the futility of current deflectors in the protection of river banks from erosion.

Levees Along the West Bank.—When the break of 1905 was closed, a levee was built to the southward for a few miles, and then turned westward toward the old overflow channel known as the Paredones. It was well known at that time that a break in the near future was imminent by way of Bee River. If, instead of carrying the levee back away from the river, it had been extended down along the river, across and well below the Bee River, which was dry except at flood stages, the break of 1910 with its attendant losses never would have occurred. It would also have been in line with "final and complete" regulation as advocated by "engineers best acquainted with the problem".

The writer discussed this matter at the time with those in charge of closing the break, and understood that the plan was to extend the levee down along the west bank of the river to what was reported to be high land well down toward the lower end of the delta. There are, in fact, evidences on the ground, in the nature of a partly constructed levee for a short distance below the point where the levee turns to the westward. It would be interesting to know what caused the change in the plans.

Hydraulic-Fill Dam Across a Flowing River.—The author's success in building, across a flowing river, a hydraulic-fill dam out of material pumped from the lower strata of the bed of the stream is a striking example of what a resourceful engineer can accomplish when an emergency arises.

In his official report of 1910 the writer suggested that the whole operation of the closure of the Bee River break "might be economically handled in the dry", by operating during a low-water season, using the temporary rock-fill dam built just below the intake, and raising it to the required height to divert the whole flow of the river through the Imperial Canal.

The writer's experience does not agree with the statement that the depth of scour is limited by the heavier material composing the bottom, and that "the materials are graded as to weight, and deposited in direct relation to the velocities". In the Mississippi River, the bars

composed of gravel larger than the shingle described by the author, extend well above low water, and the deep concave bends opposite the bars have no gravel in them at all. It is not uncommon to see coarse gravel distributed over the high-water banks. Take the exposed section of an alluvial bank in general, all of which has been deposited from a state of suspension, and there is little evidence to show that the materials are graded as to weight. Mr. Ockerson.

The scour line of the bed of the river at Yuma is also doubtless influenced by the bed-rock which extends across the river in that vicinity.

The construction of the dam described was only possible during the extremely low stage in the river, amounting to only 4 000 sec-ft., all of which could easily be carried through the head-gates to Imperial Canal. The low cost of the work fully justified the effort, and its novelty and successful outcome reflect great credit on the builder.

It is stated in the press that there is under construction a new temporary rock-fill dam which will cost several times as much as the hydraulic-fill dam under discussion, and it would be interesting to know why the latter was not repeated.

Restoration of Colorado River to Its Former Bed.—The restoration of the Colorado River to its former bed must be realized before a final solution of the problem of control is reached; and, when it is undertaken, the experience gained in the construction of the hydraulic-fill dam can be applied with success. As the author well says, closure should not be attempted under emergency conditions, as heretofore, but a favorable time should be selected, when the whole volume can be diverted down the canal through the head-gates, and then it will be possible to build "dry-shod" such dam or barrier as may be necessary to turn the flow back to its old channel. The latter would also probably need clearing out and rectifying, in order to facilitate the flow.

Railroad on Crown of Levee.—The writer cannot agree that a railroad on the crown of the levee is a "vital factor in all levee protection on the Lower Colorado"; but it may be a convenience in the work of maintenance, which cannot be neglected if the levee is to remain intact.

The writer is of the opinion, also, that, in the use of rock to protect the exposed face of the levee from erosion, economy as well as safety dictates that the rock facing shall be laid by hand with some care, instead of being dumped at random from cars, as a large part of the rock thus dumped serves no useful purpose; witness the levee north of Bee River, which was breached in spite of such protection.

Restricting the River to Narrow Limits.—The author states that "the less room the river is allowed for meandering, the greater its velocity and scouring action, and the easier it is to keep it under control". This statement needs qualification. When the Sonora Mesa

Mr. Ockerson.

is approached, only one bank of the river requires control by revetment; the Mesa itself takes care of the other bank, as do the hills on the right bank from near Yuma to Andrade, which the author cites as a narrow confined bed. Increase of velocity necessarily increases bank erosion, as well as the difficulty of control by bank revetment. Increased velocity does not mean that the energy will all be expended on the bed of the stream, for it will also attack the banks. Therefore, why not give it more lateral room, so as to reduce the flood height?

Location of the Government Levee.—The location of the Government levee on the west bank of the river was fixed after a careful study of the changes in the bank line, as shown on a map defining several positions of the river dating from the earliest surveys.

This study developed the fact that, had a levee been built 20 years earlier, and placed at a distance of 3 000 ft. from the westerly bends of the river, it would have remained intact, as far as river bank erosion was concerned.

As the project of 1910 could not cover bank revetment, it was decided to place the Government levee so that it would be safe from destruction by river bank erosion for a probable period of about 20 years, the primary object of the levee being to carry the flood-water so far down stream as to eliminate the possibility of its flowing into Imperial Valley. With the exception of the detour to connect with the Bee River crossing, which was regarded as the best available point, the levee alignment was fixed in accordance with this plan.

In a comprehensive scheme for the regulation of the Colorado River, including bank revetment and flood control, the levee alignment might be somewhat different.

River Side Borrow-Pits.—The author seems to object to river side borrow-pits which constitute a cardinal principle, followed in all parts of the world, except in the Colorado River delta; and in most of the levees built there that practice has been followed, except when prevented by the encroachment of the water on the river side.

An examination of the Government levee after the floods of 1911 disclosed the fact that there were no channels in the pits paralleling the levee, but, on the contrary, the pits in many cases were obliterated by deposits of sediment. There was no evidence anywhere that the river side pits were responsible for damages to the levee.

The imperative necessity for at least temporary protection of the river slope of the levee was fully realized by the writer, but, when proposed to those "higher up", was rejected, because there was "no authority under the appropriation or negotiations with Mexico for maintenance".

Hanlon Head-Gates.—Apparently, very little attention had been given to the hydraulics of the river, its variations in stage, and the oscillation in the elevation of the bed conforming in a measure to the

stage, until after the concrete head-gates had been placed at Andrade in 1906. Shortly after they were built, it was realized that the sill of the intake, which was 5 ft. below the bed of the river at the time, was too high, and this is what made it necessary to build temporary dams at low stages below the intake, in order to increase the head so as to divert enough water to supply the demands of Imperial Valley. Mr. Ockerson.

In July, 1910, the supply dropped to 746 sec-ft., only 395 sec-ft. reaching Imperial Valley. Much of this trouble was due to a silting up of the intake above the head-gates.

Both the United States and Mexico Interested.—A satisfactory and comprehensive solution of conserving, controlling, and using the waters of the Colorado River can only be reached by a joint commission of engineers from both sides of the International boundary line. It has already been too long deferred, and it is hoped that Mexican affairs will before long reach such a peaceful and prosperous state as to permit the consideration of the agricultural and other developments of the delta of the Colorado.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DISCUSSION ON FLOODS AND FLOOD PREVENTION*

By Messrs. Farley Gannett and C. E. Grunsky.

Farley Gannett,† Assoc. M. Am. Soc. C. E. (by letter).‡—After reading the report of the Special Committee on Floods and Flood Prevention, the thought presents itself: "What is to be done next"? It was hoped that the Committee would indicate a definite course of procedure to be followed in order to accomplish the gradual reduction of the flood hazard, but it seems that it has not done this. Some members of the Society doubtless expected to find in the report tables showing the magnitude and frequency of floods, together with flood damage estimates, and other information, but it is thought the Committee was wise in not publishing these data. Such data are most useful and necessary to accomplish the control of floods, and their wide distribution would facilitate the intelligent construction of such works, but without a bountiful appropriation, the Committee could not have been expected to collect, correct, arrange, and tabulate the vast store of records which it could have found available. A list of references to published sources of flood information, however, would have been a useful addition. Mr. Gannett.

Flood data should be collected, studied, analyzed, revised, and made available to the Profession; and would not such work be a proper avenue for the expenditure of the funds of the Society? Certain States are undertaking to do this; the United States Government, in several different Bureaus, is doing some work along these lines; individual engineers have done a great deal, but they have

* Discussion of Progress Report of the Special Committee on Floods and Flood Prevention for 1915, continued from August, 1916, *Proceedings*.

† Harrisburg, Pa.

‡ Received by the Secretary, July 26th, 1916.

Mr. Gannett.

not the resources in time or money to treat the data in the proper way; and, therefore, it seems that, if this information is to be placed at the disposal of the Profession, the American Society of Civil Engineers is the proper organization to do it, even though it may cost many thousands of dollars. It is recognized that there are other fields which probably deserve equal attention by the Society, and that all desirable fields cannot be covered simultaneously, but is there a reason for doing nothing simply because all cannot be done at once?

The Flood Committee might have been expected to publish flood height and damage data or to recommend concurrent State and National legislation which would tend toward reducing the flood hazard. The latter is believed to be by far the more important. It is one thing, however, to recommend remedial legislation and another thing to have it adopted, and that is where the real work would come.

Channel Reduction by Encroachments.—The writer must disagree with the Committee in its statement that "the obstruction of the flood plain by the works of man has in many cases largely increased flood heights for the same volume of discharge". In this discussion we are dealing with great and damaging floods on large streams, and, as a result of an intensive study of past floods and experience in passing upon proposed encroachments in stream channels, in enforcing the laws of the State of Pennsylvania in this respect, the writer thinks that, except for small floods which are confined within well-defined channels, river bank encroachments, and obstructions, have, with but a few exceptions in Pennsylvania, had small effect on flood heights. When floods are confined to channels between normal banks, their height is raised by bank extensions, bridge piers, buildings, foundations, etc., but great floods, in Pennsylvania at least, almost everywhere leave the well-defined channel and inundate the whole valley from hill to hill. During such floods, which overtop the river banks, the extension of such banks makes little or no difference in the gauge height attained.

With small streams the statement of the Committee applies more truly, however, because railroad embankments, highways, etc., crossing such streams over culverts of insufficient capacity, with long, high approach fills, often retard the flow and back up the water to damaging heights. When such accumulations of water finally overtop the embankments and cut them away, the damage and stage below are often far increased.

On Mill Creek, at Erie, Pa., with a tributary watershed of 13 sq. miles, \$2 000 000 damage was done by a flood on August 3d, 1915. This was the third great flood during the last 40 years, each doing vastly more damage than the one previous, not so much because there was more water, but because each time there was vastly more property, in houses, stores, and factories, to be damaged, and also because

inadequate culverts carrying streets over the creek, with approach fills, became clogged, backed up the water, were overtopped, and the approaches cut away, to disgorge the accumulated water down to the next culvert, where the process was repeated. Mr. Gannett.

One of the greatest obstructions which can be placed in a big river, as far as impeding the area is concerned, is a masonry arch bridge. Yet when the Cumberland Valley Railroad Company asked permission to place such a structure nearly a mile long over the Susquehanna River at Harrisburg, it was found that its effect on an estimated maximum flood of 900 000 sec-ft. (previous actual maximum flood 700 000 sec-ft.) would be to raise it 0.9 ft. over what it would be without a bridge.

Encroachments, however, are going on in every place where no control over them is being exercised; and, if permitted to continue, will in time become of consequence. Heretofore, except at a certain limited number of places (considering only large streams), they have not become of damaging dimensions, but, as every little bit tends in the wrong direction, all encroachments which would tend to restrict flood discharge below safe limits should be prohibited. Few States have legislation on this subject. Until recently, the National law regarding the building of structures in navigable rivers was not enforced from this point of view. The length of rivers classed as navigable is so great, and the corps of engineers available to the War Department to enforce this law is so small, that an attempt to carry out its provisions is only made at certain points.

Pennsylvania has had a good law, well enforced, for 9 years, controlling encroachments along, or obstructions in, stream channels, and a vast benefit has resulted, not so much in bettering previously existing conditions as in preventing worse conditions from arising; and improvements over previous conditions have been obtained at many points. This law prevents the dumping of wastes of all kinds over river banks, unless the slopes are protected, and thus tends to reduce silt carriage by the streams, to be deposited lower down. None of the neighboring States has such laws, and there is nothing to protect Pennsylvania from receiving in its rivers the washings of refuse from banks in States up stream.

Such a law, enacted by all States, modified as necessary to meet local conditions, is a prime requisite and a most proper recommendation for the Flood Committee to make, in order to preserve the streams as they are, prevent them from getting worse, as far as channel capacity is concerned, and to effect a measure of improvement whenever opportunity offers.

The Popular Fear of Dams.—Another thing which the Society can do to further flood control is to assist in disabusing the public mind of the idea that a dam is a dangerous structure. As a result of

Mr. Gannett. several disastrous dam failures, two of them in Pennsylvania, the public has the idea that a dam is bound to be a grave source of danger, and the location of such a structure above a city a menace. The broadest schemes of flood control cannot be developed unless this feeling is removed, and it can only be removed by a concerted campaign of publicity such as could and should be carried on by the American Society of Civil Engineers.

Surveys and estimates at Erie showed that the most satisfactory as well as the most economical method of controlling floods in Mill Creek was by the construction of a detention reservoir and a conduit 18 ft. wide; but, on account of the feeling in Erie against a dam of any kind, and of the necessity of going before the people with a bond issue election for funds with which to construct the flood control works, it was decided to adopt an alternative plan of a much larger conduit and omit the dam entirely, at an added cost of more than $100 000. It was believed by the City Commission that if a plan involving a dam was submitted to the voters the bond issue would fail. Without the dam, the bond issue of $950 000 carried by a five to one vote. The City Commission of five members was unanimously in favor of the plan involving a dam, as opportunity was afforded to convince them of its advantages by frequent discussions; but such methods could not be applied to the entire population in the short time available. Therefore the furtherance of a propaganda favorable to dams, and the spreading of the conviction that dams are not dangerous, would be an important function which the Society could assume in furthering flood control.

Multiple Use of Reservoirs.—The writer believes, with Gen. Chittenden, that reservoirs may be utilized satisfactorily for flood control and other purposes as well. He had occasion to work out this problem on two large storage projects, and in one of these cases it was thoroughly proved that a reservoir, designed primarily for increasing the dry-weather flow for industrial use, would reduce floods in the congested section of the river below, by 30% in height, and would practically eliminate damage. In the other, by raising a proposed masonry dam for water power a very few feet, almost complete control of floods on a water-shed of 1 200 sq. miles, would be effected. In the former case, the reservoir is long, wide, and shallow, covering 30 sq. miles, on a water-shed of 150 sq. miles. The absorption of flood flow by this reservoir would be enormous, a 3-ft. rise absorbing an 8-in. rainfall on the water-shed. The freeboard on the dam is 10 ft. In the latter case, the dam is about 260 ft. high, and the reservoir more than 40 miles long. The capacity curve of this reservoir is such that a few feet on top gives capacity equal to a large percentage of the volume below the level required for water power.

With few exceptions, storage in the upper part of a reservoir is the cheapest, so that, by increasing the height of dams erected for other purposes to a height greater than necessary for that primary purpose, the necessary storage for flood absorption will be obtained at more reasonable cost than if a dam or reservoir is built only for flood control. Mr. Gannett.

Several of the European nations have in this way created effective control and utilization of important streams. Thus, storage developments on the Oder River, in Silesia, has effected flood protection in the valley below and has also permitted the generation of several thousand horse-power; storage for navigation improvements on the River Rhône has reduced flood heights below storage reservoirs constructed with both ends in view.

Floods come so seldom, strike at so widely different parts of the land, and at such varied seasons, that in the popular mind they have come to be accepted as acts of Providence. This superstition is being gradually eliminated, but the feeling is still prevalent that floods, like lightning, never strike twice in the same place, and so there is no use trying to do anything about it. Furthermore, the writer thinks most engineers will agree that it is impossible to construct flood control measures, where a likelihood exists, if a damaging flood has not occurred, that the financial and governing bodies will refuse to "lock the barn door before the horse is stolen," even though one can show the presence of thieves in the vicinity and the absence of locks on the doors. Flood protection or control measures are usually very costly, and floods seldom recur in any one place, and it is impossible to prophesy how soon the next one will come, so that it is impossible to determine exactly the amount of money which can be expended economically for such works. Again, it is usually necessary in large flood control projects to obtain the co-operation of corporations, cities, counties, States, and the Federal Government, or several of them. All these conditions, as well as numerous others, make the final accomplishment of water storage measures, for flood control alone, a long and laborious undertaking, so long that often the necessity therefor and the losses and horrors of the last flood have been measurably forgotten before all these steps can be accomplished, and the project fails.

For these reasons the writer believes that real widespread flood control through reservoir construction and storage will be brought about by the construction of reservoirs principally for other utilization purposes, such as water supply, water power, industrial use, navigation, irrigation, and for esthetic purposes, such as park lakes, improvement, sanitation, etc.

Our existing State laws, under which most works of this kind would be and are built, will have to be amended in most States to

Mr. Gannett. provide a means by which such multiple use may be made of reservoirs through the division of cost between, for example, a corporation building a water-power reservoir and a city desiring flood control, or between one city desiring water supply and another requiring flood control, etc.

Such legislation has been suggested for Pennsylvania, but has not yet been placed on the statute books. Projects involving several hundred thousand continuous horse-power are now chartered by this State, but remain unbuilt, because of the lack of definite and favorable water-power laws under which they may be built and operated. Others are too costly, as water-power projects alone, to warrant construction in this State, the home of coal. With favorable water-power laws, and with the right to co-operate with municipalities, counties, and the State, many hundreds of thousands of horse-power, now going to waste, would be developed; many towns and cities would have reduced flood hazards, navigation on several large rivers would be improved, and sanitary conditions along the water-fronts of many river communities would be greatly benefited.

Thus another line of legislative enactment, essential to the promulgation of flood control, is the passage of laws permitting and facilitating the generous development of water supply, water power, and irrigation projects, and the division of the cost of constructing and operating them between corporations desiring such works for financial return, and municipalities, counties, States, and the Federal Government desiring them for flood control and navigation.

The Water Supply Commission of Pennsylvania approved of the incorporation of a large water-power project in the western part of the State, involving the construction of large storage reservoirs and the installation of 200 000 h. p., on condition that the operation of the main storage reservoir be subject to the direction of the Commission, as respects maintaining a certain dry-weather flow below it, and as respects absorbing floods.

Forests.—The writer thoroughly agrees with Gen. Chittenden in his contention that, though forests may and probably do mitigate ordinary floods to a certain extent, they do not affect the volume of discharge in great floods. Anything but circumstantial and theoretical evidence on this point is impossible to obtain. The studies which were made of Pennsylvania river floods showed that whenever we could go back 75 or 100 years, substantial and reliable records of floods were often found exceeding anything in more recent years, since the forests were largely removed. This was clearly shown by finding accurate records of two floods at Pittsburgh, in 1762 and 1763, considerably exceeding that of 1907. Also by finding records of a flood on the Susquehanna River at Wilkes-Barre, in 1865, exceeding that of 1902 by several feet in height, and floods in 1784

and 1807 nearly as great. A flood in the Schuylkill River in 1850 exceeded that of 1902 materially. These facts prove nothing, but they show that the dense forest growth, which covered the State at the earlier dates, did not prevent great floods, which, if they occurred to-day, would be truly disastrous. Mr. Gannett.

Detention Reservoirs.—The writer cannot but feel that on large streams, where water power might be obtained, or where navigation improvement might be gained by storage, detention reservoirs are an economic waste. It is unfortunate that the greatest and most spectacular flood control project of our time, the Dayton project, is planned on that principle. The conditions there apparently made that the only plan that could be adopted, just as at Erie, conditions made the plan without a dam the only one that could be put through. The Erie case also is unfortunate, but being smaller, the failure to utilize the best and most economical method is not so harmful, as it is not so widely known and will not be pointed to so frequently as a precedent as will the Dayton project. The failure to utilize the power of the Scioto River and its tributaries, which, with permanent reservoirs of greater capacity, might have been made available, will set a precedent which will undoubtedly lead to the utilization of this plan elsewhere, where the conditions are not the same and where complete utilization and conservation would have been practicable.

Flood Warning.—The worst feature of floods is the damage they do to life and property. There are two ways of reducing this damage, one is to control the floods and lessen their height, and the other is to get out of the way of them and remove perishable property to places above flood height. The first proposition has been much discussed, but the latter, it seems, has not received the attention it deserves. This involves flood warnings. By timely warnings many lives can be saved and much valuable, perishable property can be removed beyond the danger zone. Until the far-distant day when flood control is general, more attention should be devoted to early and accurate flood warnings.

The Federal Government maintains a flood warning service which has proved itself of great value. It is a Herculean task, however, to send flood warnings over this vast land of ours, and the means at the disposal of this bureau have confined its work to certain points and a limited number of streams.

Following the flood of March, 1913, which visited streams in Western Pennsylvania, a law was enacted, and \$10 000 was appropriated by the State Legislature, with which to give to the people a more intensified flood warning service than was possible by the United States Government. This law was drafted with the approval of a United States Weather Bureau representative, and in the 3 years during which it has been enforced by the Water Supply Commission,

Mr. Gannett. a great quantity of property has been saved from damage. A larger appropriation would make greater savings possible. In Pennsylvania, however, this service is hampered by the lack of similar service on the head-waters of the Susquehanna, Allegheny, and Delaware Rivers, which rise in New York and pass through or along the border of Pennsylvania for hundreds of miles.

Either by vastly increasing the resources of the United States Weather Bureau for flood warnings, so that it could give attention to other than the few great rivers of the country, or by adopting uniform flood warning legislation in the several States, much loss in life and property could be prevented while we are waiting for control works to be built.

An important duty of such a service is also that of warning prospective constructors of railroads, highways, bridges, factories, mills, and dwellings of the limits of the flood zones of rivers, so that they may not locate within such area, or if they do, that the building site may be elevated above flood level. If there were such an organization in each State, under State or Federal control, and the people knew of its existence, as they would if proper publicity was given to it and its work, then it would be possible to reduce greatly the increase in the damageable property which is constantly being placed in the way of floods.

In conclusion the writer would suggest that it is the province of this Society to do three things:

1.—Place at the disposal of its members full and accurate flood data;

2.—Change the popular fear of dams into an understanding of their security;

3.—Formulate and push through the adoption of legislation along these lines:

A.—To control obstructions and encroachments in or along streams;

B.—To permit of co-operation between corporations, States, municipalities, and the Federal Government in the construction and operation of storage reservoirs for water power, water supply, and other commercial uses, so as to adapt them for flood control as well;

C.—To extend the Federal, or establish a State, flood warning service.

Mr. Grunsky. C. E. GRUNSKY,* M. AM. SOC. C. E. (by letter).†—The discussion which the Committee's report has provoked is of a character fully justifying the report, notwithstanding the fact that the Committee

* San Francisco, Cal.

† Received by the Secretary, September 5th, 1916.

was not in a position to attempt to say the last word on the subject of flood control. Mr. Grunsky.

Some of the statements made by those who point out the incompleteness of the report merit reply, in order that wrong impressions may be corrected. Mr. Eakin says: "It is indirectly stated that the use of levees effects an increased channel storage that induces a lowering of flood levels." No one who knows anything about the propagation of a flood wave could by any possibility intentionally make the statement that the reduction of the flooded area which results from the construction of levees will reduce the elevation to which water will thereafter rise between the levees. The language used by the Committee (of which the writer was a member) is therefore unfortunate. The levees are put on the banks of rivers for the purpose of confining the water to a restricted channel and thereby increasing the rate of flow in this channel, and this cannot be done without causing the water between the levees and within the channel to rise to greater height than that which would have been attained without levees. It takes the crest of a flood wave 10 days, or about that time, to travel in the Mississippi River from Cairo to New Orleans. Let it be assumed that at flood the volume of flow is such that levees confine the water to the river and to bank-land areas between the levees. It is evident that in such a case the discharge of the river in excess of ordinary flow for about 10 days before the cresting of the flood at New Orleans has been consumed in filling the river channel above that point from a low to a high stage. It is also evident that this channel storage is greater than it would have been if there had been no levees. To the extent that this increase of channel storage is made possible by the levees it is a factor making for a reduction of the maximum flow at all down-stream points.*

Channel storage between levees does not reduce the total run-off, and it does not reduce the water surface elevation of the river at flood, unless this be in the exceptional case of scour, which may result from the higher velocities in the channel between levees than existed under natural conditions. No claim can be made, and none was intended to be made by the Committee, that the confinement of water by levees will decrease the original maximum stream flow at the mouth of the river. Levees are built for the purpose of reducing flooded areas. They are built to keep water away from land that without them would be less desirable for agricultural, industrial, and other uses. Consequently, for the same volume of flood flow, the opportunity for storage, taking the river basin in its entirety, is less after levees are built than before. The flood wave reaches the mouth of the leveed river with less elongation than under natural conditions, and con-

* See *Transactions*, Am. Soc. C. E., Vol. LXI, p. 332; and also Report of Commissioner of Public Works of California, 1895, p. 130.

Mr. Grunsky. sequently the discharge at the peak must be greater. As an illustration, the Sacramento Flood Control project may be referred to. Under natural conditions the floods of Sacramento River inundated broad lateral basins, and the lower reaches of the river had a maximum flow of about 200 000 sec-ft. The withdrawal from inundation of the islands of the delta region of this river and of the various flood-basins which border the river will increase the momentary flood maximum to more than 500 000 sec-ft. Of this quantity, in the latitude of Sacramento, it is proposed to hold as much as possible in the river, 20 to 30%, confined between levees of reasonable height, but at elevations which at extreme flood will be about 7 ft. higher than the original river flood-plain. It is the additional channel storage represented by this added depth of water which the Committee had in mind when it referred to "the resultant reduction of flood height." What the Committee desired to do was to call attention to the added storage as a factor making for elongation of the flood wave and consequent reduction of maximum discharge, without any intention of claiming that channel flood heights as originally existing would be reduced by the construction of levees.

In connection with this matter, and in reply to the remarks of Gen. Chittenden, the general principle should be kept in mind that the elongation of a flood wave as it passes down stream is due to the effect of storage. If there were no change possible in the volume of water in storage between an up-stream and a down-stream point, as in the case of a closed conduit, there could be no elongation of the flood wave. The accession of water at the upper point would at once be manifest by an increased discharge in equal quantity at the lower point. Storage, whether in the channel or in overflow basins, has the effect of elongating in some measure every flood wave that travels down a river, and by such elongation the time of passage is increased and the flow at the peak is correspondingly reduced. It follows, as demonstrated by the writer in a paper prepared in 1880 while he was Assistant State Engineer of California, and published in 1895 in the Report of the Commissioner of Public Works of California,* that the maximum discharge of a river which receives no accessions from tributaries will decrease with distance down stream. Every decrease of available storage space, such as may result from a contraction of the waterway, will reduce the effect of storage and will tend to increase the maximum discharge at down-stream points. Every increase of storage space, resulting from the raising of levees or the adding of retention reservoirs, on the other hand, will decrease the maximum flow at down-stream points.

The Committee shares the view expressed by Mr. Eakin when he says:

* See also *Transactions*, Am. Soc. C. E., Vol. LXI, p. 332.

"No individual or organization has as yet commanded such proficiency in all these sciences as to enable them to outline a programme of river treatment with dependable authority." Mr. Grunsky.

Herein lies the justification of the Committee in presenting a report in which the shortcomings were known to the members and which was not put forward as exhaustive on the subject of flood control, a subject which necessarily presents as many different aspects as there are river systems.

It happens frequently, as in the case of the Sacramento and San Joaquin Rivers, in California, that some of the natural flood basins along these streams, such as Butte Basin to the northward of the Marysville Buttes, Upper Colusa Basin on the west side of Sacramento River, and, to a lesser extent, Sutter Basin, Lower Colusa Basin, and American Basin, and some of the submersible lands along the San Joaquin River, partake of the nature of the lands which in connection with flood-control projects on other river systems are selected for detention reservoirs. The demand is strong in the California case for the protection of these submersible valley lands against overflow. It becomes an economic question, then, to determine where the line should be drawn, and it is by no means certain that complete protection against floods is in all cases justified. Occasionally, it will be found advisable to retain a natural overflow basin, not only for the control of the floods which it helps to effect, but also as a recipient of some of the silt carried by the stream. The permanent utilization of a natural flood basin seems particularly desirable when the basin is situated so that, while acting as a detention reservoir, it can be drained of its water in time to leave the land available for the cultivation of summer crops. In 1850 the United States gave to Arkansas and a number of other States, for the purpose of reclamation, the land which was segregated as swamp and overflow, and these several States thereupon proceeded to divest themselves of ownership as rapidly as possible. They blundered. The land subject to inundation should have remained in public ownership until comprehensive plans for flood control were made. It would then have been a simple matter to have the plans carried out in proper sequence, and much embarrassment would have been avoided that now results from the demand that protection be provided for lands which, if they were not in private ownership, would to no inconsiderable extent be put in a class requiring only partial protection or fair protection against ordinary and not extraordinary floods.

Mr. Hill points out that the extreme floods of recent years are not due to changed climatic or physical conditions. The example which he supplies of an extreme flood stage in the Great Miami in 1805 before forests had been removed suggests that it would not be out of place to refer to some additional facts to show that a connection

Mr. Grunsky.

between deforestation and stream flow will remain difficult to establish.

The writer, in a paper presented to the Society some years ago,* has shown that the dominating cause of changes in the surface elevation of the Great Lakes is the climate, and that a long period of less than normal rain and snow may be followed by another with more than the normal. A still better example to illustrate the variation in the rainfall and run-off is the Great Salt Lake. This lake was very low when visited and sounded by Capt. Stansbury in 1849. It was low when visited by Fremont some years earlier. In the years preceding 1869 it rose, ultimately reaching an elevation about 11 ft. above that of 1849, and then, with numerous minor fluctuations, decreased in extent and in elevation until 1906, when its water surface was about 4 ft. lower than it had been in 1849. It was supposed by many that, on account of the increasing utilization of water for irrigation on its water-shed, the lake would never again rise to anywhere near the high stages of 1868 to 1876, but this view was in error. The lake is now about 8 ft. higher than it was at its lowest stage in 1904, having maintained this high stage for several years. For a long time preceding the low period of 1849, and extending to about 1861, the rainfall in the region tributary to Salt Lake as a water-shed must have been less than normal. Then followed a number of years in which, taken collectively, there was more than normal rain, until about 1876, after which there came another period with less than normal rain as the average for a number of seasons. The consequent decrease of run-off and the increasing use of water for irrigation brought the lake to its lowest stage in 1906. In the case of this lake, which has no outlet, the rise and fall is a fairly good index of the run-off, and therefore of the rainfall, when groups of consecutive years are considered. The problem, moreover, is not here complicated by deforestation. It appears from this and numerous similar cases that very large variation in the seasonal water production of any region may be anticipated, and that the persistence of any tendency which the seasonal run-off may have to increase or decrease for a number of years is not to be accepted as conclusively demonstrating either a permanent change of climate, nor yet that such increase or decrease is in any way related to aforestation or to deforestation of water-shed areas. The same general statement will apply also to the possible momentary maximum stream-flow. The factors affecting the rate of run-off are, moreover, so many and so inter-related that it will remain difficult if not impossible to make a conclusive determination of the effect of forest growth on flood discharge.

Mr. Leighton is evidently of the opinion that no report on the subject of flood control can be a well-considered report which does not

* *Transactions*, Am. Soc. C. E., Vol. LXIII, p. 31.

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recognize the forest as one of the material factors which influence the magnitude and frequency of floods. Much as the writer has studied this subject, he has yet to find any convincing demonstration that there is such an effect. Generally, the individual cases cited are so complicated by related circumstances that the evidence is not conclusive. The writer is not prepared to accept, and does not believe that the Profession will accept, as final, any mathematical demonstration that forest growth will markedly reduce or meliorate flood conditions. If the statement made by the Committee gives the impression that the quantitative influence of the forest on the frequency and magnitude of floods is not proved, this is exactly what one member of the Committee, at least, intended. This is without prejudice to the forest, which the writer would like to see extended and maintained to meet fully at all times the requirements of the country. The writer, moreover, does not wish to be classed among those who will not concede that it may yet be possible to demonstrate the true relation of the forest to the flood; and, for that reason, he subscribed to the statement in the report that the exclusion of the forest as a method of flood prevention had not yet been demonstrated, though he believes that, except in the rarest cases, conditions will never be such that the forest will become a material factor.

The maximum stream flow is not dependent solely on the rainfall and the rate at which snow is melting; it depends also on the condition of the surface of the ground on which the snow lies or the rain falls. Usually, the period of intense rain which produces flood stages is preceded by rain which saturates more or less thoroughly the top layers of the soil. This is least likely to occur in sandy and gravelly regions and where loamy soils are well tilled and are deep. It is most likely to occur in regions where the ground is swampy and naturally full of water, or where the flood-producing rain falls on frozen ground which requires but little water for complete saturation. It follows that, whenever a region which in its natural condition was swamp has been made arable and brought under cultivation, the probability of complete saturation preceding a flood-producing rain will have been reduced, and some effect on the frequency and intensity of the flood condition in such a region will have to be conceded to the reclamation work. The main effect of any such modification of surface conditions should be sought in terms of water storage and retardation of the flood wave, because, if thereby the resultant elongation of the flood wave can be determined, some basis will exist for estimating the quantitative effect on the maximum flow. The writer agrees with the comments of Gen. Chittenden in this regard, and shares his view that the modification of the effect of soil cover and absorption by Man's occupancy and use of the soil will be a negligible factor in the excessive rainfalls which produce great floods.

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In the light of present information, the writer agrees too with Gen. Chittenden when, after referring to the aggravation of flood damage which results from the obstruction and use by Man of Nature's overflow channels, he says:

"The foregoing remarks disclose the reason why flood destructiveness is increasing. It is not because floods themselves are increasing, either in frequency or intensity, but because property subject to destruction is very greatly increasing, and as yet protective work does not keep pace with this increase."

The writer, though having qualifiedly subscribed to the Committee report, is not in full accord with its reference to outlets. Concentration of the flood flow in one channel is desirable. Separation into a number of channels is undesirable. The conditions, however, are not always such that a single channel can be given adequate capacity to carry all the water presented at flood. The study of the question what to do when this is the case led the writer to formulate certain principles for the treatment of Sacramento River floods,* substantially as follows:

First.—Make the river carry as much water as possible between levees of reasonable height.

Second.—Let the flood-water in excess of capacity between levees go out of the channel at selected points under control.

Third.—Confine the outgoing surplus waters to limited areas, and keep them under control until they may re-enter the river or can be delivered into the bay.

The writer has not modified his views in this respect, having, subject to these principles, always been in favor of relief weirs or controlled outlets. These are not to be confounded with ordinary outlets which begin to function before the river has reached the danger line and which become secondary branches of the stream. It is outlets of the latter kind, in the sense of a division of the stream, which with good reason are disapproved by the Committee.

The writer is pleased to find Gen. Chittenden in accord with the writer's view that the cut-off is generally a desirable improvement, and that the fear that shortening a river channel will interfere with its usefulness as a commercial highway is not ordinarily well grounded. The sketch, Fig. 5, is from an old document, and shows the extent to which, by intelligent direction and restraint, the course of the Rhine in the vicinity of Germersheim was modified during the period from 1817 to 1861. This sketch shows channel shortening and alignment modification quite comparable to that which might be carried out on the Mississippi, on the Missouri, or on the Colorado, if the necessary outlay, including permanent bank revetment, were justified, and the occupancy and use of the bank-lands do not already set a

* Report of Commissioner of Public Works of California, 1894–95, p. 59.

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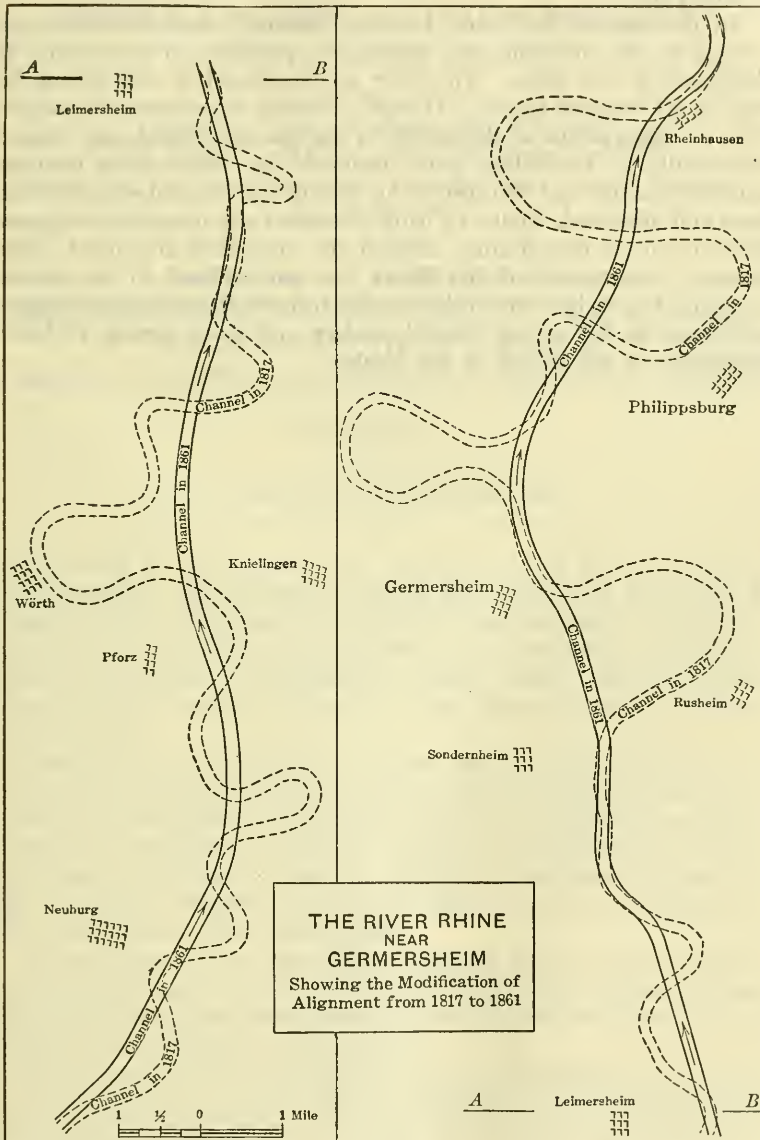

FIG. 5.

Mr. Grunsky. limit to the alignment corrections which might otherwise ultimately be hoped for.

In the case of the Rhine, the 1817 channel length of 63.5 miles, covered by the diagram, was reduced by cut-offs and corrections of alignment to 27.6 miles. The river was shortened in this stretch by 46% of its original length. Though a stream of considerable magnitude, having a width of about 800 ft., the channel control was effected successfully by excavating guide channels, by constructing training walls of fascines and brushwork, by obstructing the old channel with dams and dikes and, finally, by bank revetment and protection wherever the river in its meanderings reached the prescribed alignment. The channel improvement of the Rhine was not confined to the stretch shown by Fig. 5, but extended for miles in both directions therefrom—up stream as far as the Swiss boundary and down stream to below Mannheim at the mouth of the Neckar.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

Discussion.*

By Franklin R. McMillan, Esq.

Franklin R. McMillan,† Esq. (by letter).‡—In the following remarks attention will be given to the questions raised by Mr. Ernst F. Jonson, in his discussion, rather than to the method of calculation proposed by the author; for these questions, which concern the fundamental calculations of reinforced concrete beams, must be settled before we are justified in passing to the refined methods suggested by Mr. Janni. Mr. McMillan.

During the past 3 years, the writer has been conducting, at the Experimental Engineering Laboratory of the University of Minnesota, a series of investigations concerning some of the physical properties of concrete which Mr. Jonson has mentioned as affecting the theory of flexure of reinforced concrete. Although these investigations are still far from complete, considerable data have been accumulated which relate to the questions at issue.

As the value of such calculations as made by Mr. Jonson depends on the correctness of the assumptions, it will be well to present a summary of the more important facts and conclusions from these investigations before taking up the discussion.

These results relate principally to the shrinkage and the non-elastic deformation or time yield in reinforced concrete beams, slabs,

* Discussion of the paper by A. C. Janni, M. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† Asst. Professor, Structural Eng., Univ. of Minnesota, Minneapolis, Minn.

‡ Received by the Secretary, September 2d, 1916.

Mr. McMillan. and columns.* The curves of Figs. 5, 6, and 7 show the results of shrinkage measurements on a number of specimens designed to bring out the effect of several variables. In regard to Fig. 5 little need be said in explanation, as the legends show quite clearly the variations. These results were obtained from 4 by 5 by 24-in. specimens, cast under conditions as nearly identical as possible, and cured side by side, 2 weeks under wet burlap and then open to the ordinary air of the laboratory. Initial readings were taken when the beams were one or two days old, hence the values given represent practically the entire shrinkage. From these curves it will be seen that the total shrinkage is from 0.055 to 0.065%, and that little difference results from varying the proportions, quantities of water, or density, within the limits of ordinary practice. It will also be observed that in nearly every case the shrinkage amounts to 0.05% within the first 60 days.

On Fig. 6 are shown the results of shrinkage measurements extending over periods of from 2 to 3 years, in which somewhat higher values are found than in the specimens of Fig. 5. It will be noted that there is a large difference in the total shrinkage shown by the two slabs in the upper diagram, and that the greater value is shown for the slab on which observations were not commenced until it was 68 days old. As this slab had been covered with wet sand until within 3 days of the zero measurements, there may have been some swelling, which, if subtracted from the values shown, would give the shrinkage from the original state. In some other tests, not included here, a swelling of nearly 0.02% has been observed in 80 days under wet burlap. The concrete of the 6 by 8-in. slab is considerably more porous than that of the 10 by 10-in., which may in a measure account for the higher shrinkage, as well as for the quicker response to the change in the humidity of the air, as seen from the undulations of the shrinkage curves. It should be noted that the periods shown on this or any of the other figures do not represent coincident calendar periods for the different specimens; they were plotted to the same set of co-ordinates for simplicity. When plotted on a true calendar scale it is found that the undulations are coincident, showing the seasonal changes in the humidity.

In the lower diagram of Fig. 6 rather high values of total shrinkage are shown, also the effect of early wetting on the total shrinkage can be seen. These two beams were identical, except for the methods of curing, as noted on the diagram. That the effect of the early wetting on Beam *B*—or the subsequent immersion—is only to retard the shrinkage, and does not affect the final total amount, can be seen

* For a more extended discussion of these tests, see *Bulletin No. 3, Engineering Series*, University of Minnesota, "Shrinkage and Time Effects in Reinforced Concrete". Also the paper, "Time Tests of Concrete," by F. R. McMillan, *Journal*, Engineers' Club of St. Louis, Vol. 1, No. 4.

Mr. McMillan.

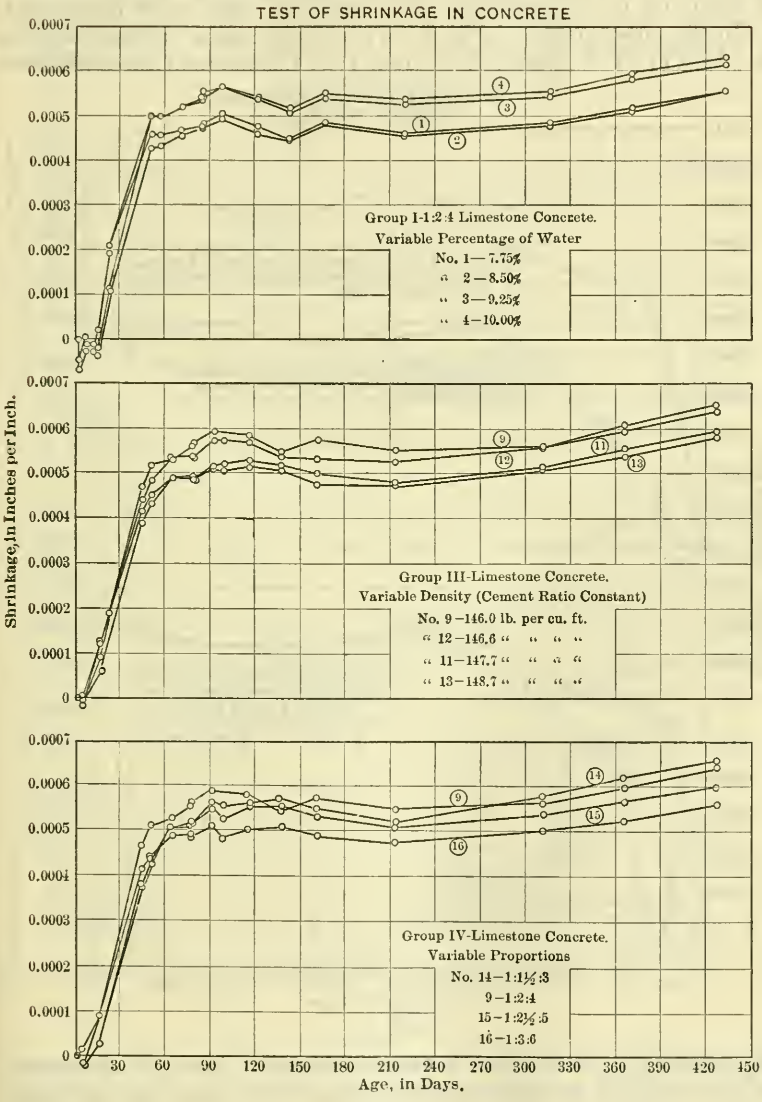

FIG. 5.

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from these curves. This is also indicated by the results from the 6 by 8-in. slab previously referred to, which show a total shrinkage of nearly 0.1 of 1% beginning after curing 57 days under moist sand.

In the upper curves of Fig. 7 are given the results of measurements on 4 by 5 by 24-in. beams, made from 1:2:4 concrete of three different

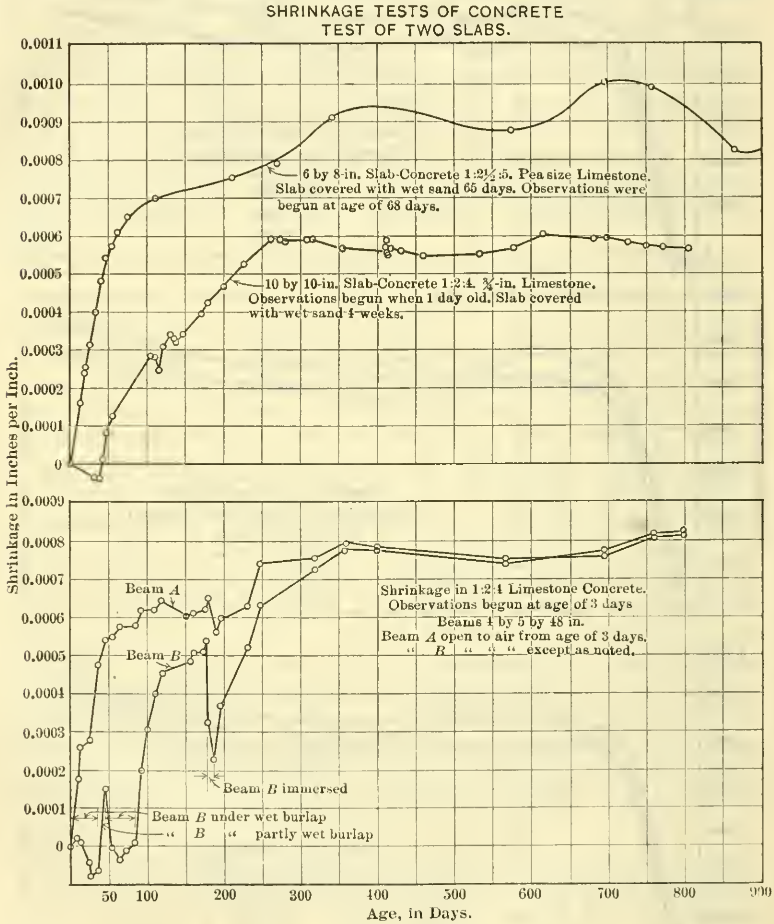


FIG. 6.

aggregates, and cured under conditions as nearly identical as possible. These results are presented as further evidence of what total shrinkage may be expected, rather than for the comparison of the different aggregates, for with these few tests definite conclusions cannot be drawn. In the lower curves the effect of early wetting on both the

limestone and sandstone concrete, as well as the comparison of the two aggregates, may be seen. Mr. McMillan.

That other variables than those controlled in the several series of these tests affect the amount of shrinkage is evident from the varying amounts shown by specimens of nominally the same mixture; for

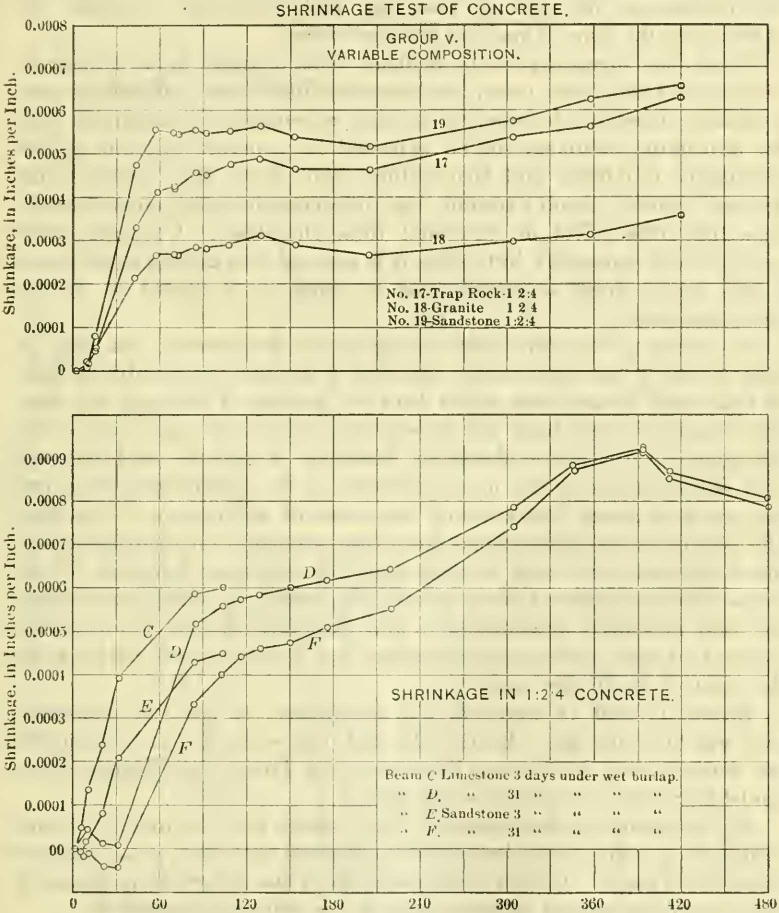


FIG. 7.

example, the 1:2:4 limestone concrete, shows the following values for the different tests: in Fig. 5, from 0.055 to 0.065%; in Fig. 6, from 0.06% for the 10 by 10-in. slab to 0.08% for Beams *A* and *B*; and, in Fig. 7, 0.09% for Beam *D*. This is further illustrated by the values of 0.065 and 0.092% shown by the upper and lower curves for

Mr. McMillan. the 1:2:4 sandstone concrete of Fig. 7. These differences are considerably greater than found for those tests shown on Fig. 5 in which the variables were regulated. Among other causes to which these differences may be due, the following are suggested as probably having considerable weight: variations in materials assumed to be the same, and differences in mixing, tamping, and otherwise handling the materials at the time of making the specimens.

From the foregoing it is evident that definite laws cannot be formulated from these tests; however, two important conclusions may be drawn: First, as to amount, it may reasonably be concluded that the minimum shrinkage to be expected in concrete allowed to dry thoroughly is 0.05%, and that values from 20 to 50% greater than this will usually result; second, the difference in early curing conditions has little effect on the final total shrinkage. Concrete cured wet will swell somewhat, but, when it is exposed to a drying atmosphere, it will shrink fully as rapidly and as much as if placed in the air when first cast.

In regard to the time yield or non-elastic deformation, the data on Figs. 8 and 9 are presented. On Fig. 8 appear the results of tests on four small beams kept under load for periods of 200 and 500 days. The details of these tests are shown quite clearly by the notes on the diagrams; in further explanation, however, it may be said that the total deformations at the upper surfaces of the beams were measured over an 8-in. gauge line crossing the point of application of the load. The shrinkage was determined from measurements on identical beams cured similarly but held without load for the same period. As the stress increases rather rapidly toward the center, in such a short span, the total measured deformations—and therefore the net deformations shown by these curves—are somewhat less than the true value, probably from 5 to 10 per cent.

Beams 11 and 13 were of 1:2:4 concrete, of pea size limestone, kept wet for one day. Beams 118 and 121 were of 1:2:4 concrete, the former with ¼ to ¾-in. limestone, the latter with Kettle River sandstone; these were kept wet 3 days.

An inspection of the curves of Fig. 8 shows that the moduli of total deformation reduce considerably in the periods for which these measurements were made. Table 2 gives the ratio of the deformation shown by these curves at several different ages to the initial deformation.

In Table 2 the remarkable regularity in the values for the three limestone beams, 11, 13, and 118, should be noted. Although the initial moduli may differ, the rate of the progressive movement is about the same. No determination of the elastic modulus was made on the concrete of these beams at the time of loading, but calculation from the bending moment indicates values ranging from 1 600 000 to 2 200 000 for the limestone, and 3 000 000 for the sandstone.

Mr. McMillan.

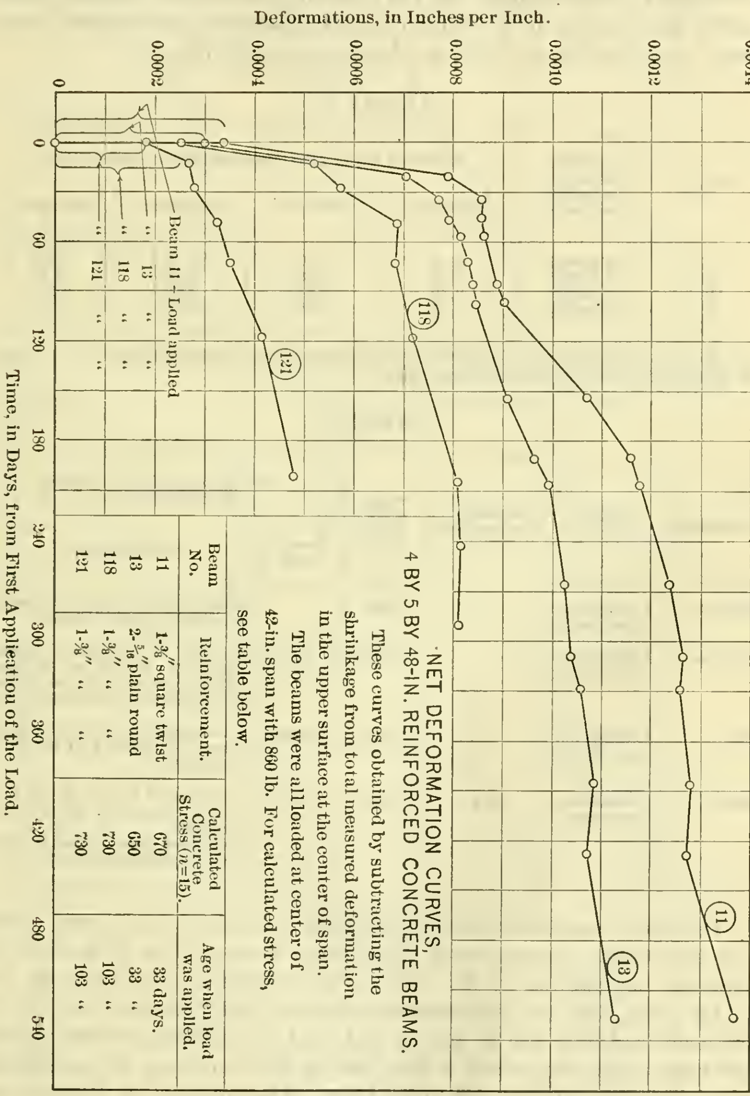


Fig. 8.

Mr. McMillan. In these calculations the conditions of a homogeneous beam, 4 by 5 in. in cross-section, were assumed, as it is known that no cracks developed at first loading. On the basis of these values, we may expect at 200 days a value of n from 26 for the sandstone to 50 for the limestone, and from 50 to 60 for the limestone at 500 days.

TABLE 2.

Beam.	Initial deflection, in inches per inch.	Ratio of Net Deflection to Initial Deflection.			
		30 days.	90 days.	200 days.	530 days.
11	0.000335	2.49	2.66	3.50	4.09
13	0.000302	2.48	2.78	3.28	3.74
118	0.000246	2.40	2.84	3.29	....
121	0.000180	1.57	2.08	2.68	....

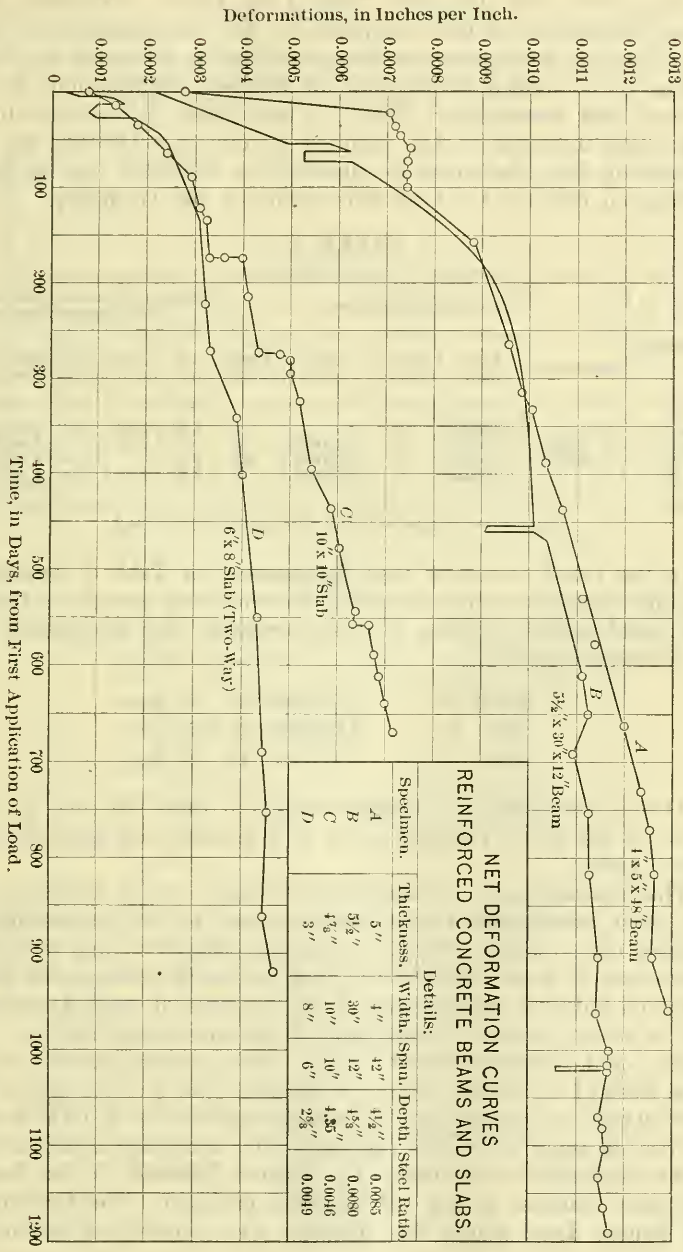
By net deformation is meant total deformation minus the shrinkage. It includes the deformation due to load and time yield.

TABLE 3.

Specimen.	Coarse aggregate.	Nominal proportions.	Time kept wet.	Age at Application of the Various Loads.	
				Dead load.	Other loads.
Beam *A*....	Limestone, pea size.	1 : 2 : 4	1 day	......	Dead load and 860 lb. at center applied at age of 33 days.
Beam *B*....	Limestone, ¼ to ¾ in.	1 : 2 : 4	(not wet)	41 days	Loaded at one-third points. Total of 500 lb. at 80 days. After several changes, on and off, total of 1 500 lb. at 88 days.
Slab *C*.....	Limestone, ¼ to ¾ in.	1 : 2 : 4	31 days	135 days	Live load 50 lb. per sq. ft. at 309 days. Increased to 100 lb. at 410 days.
Slab *D*.....	Limestone, pea size.	1 : 2½ : 4	57 days	59 days	Live load 50 lb. per sq. ft. at 68 days. Increased to 100 lb at 71 days. Live load removed at 82 days, and re-applied at 94 days.

On Fig. 9 are shown the net deformation curves for two more beams and two slabs. These curves differ from those of Fig. 8 in that the load was not applied at one time. For example, in the curve for the 10 by 10-in. slab the deformation shown at the first day was due to the dead load only (55 lb. per sq. ft.), and no further load was applied until the 174th day, when a live load of 50 lb. per sq. ft. was added, with a similar increase 100 days later. The increase in deformation at 560 days was the result of an overload applied for the purpose of breaking the concrete in tension, which, up to this time had shown no signs of cracking. Table 3 gives the mixture, age, and loading

Mr. McMillan.



Specimen.	Thickness.	Width.	Span.	Depth.	Steel Ratio.
A	5″	4″	42″	4½″	0.0085
B	5½″	30″	12″	4⅝″	0.0080
C	4⅞″	10″	10″	4.35″	0.0046
D	3″	8′	6′	2⅝″	0.049

FIG. 9.

Mr. McMillan. of these beams and slabs, and Table 4 the ratios, at different ages, of net deformation to load deformation. In the calculation of these ratios, the net deformation at the given age, as shown by the curve on Fig. 9, is divided by the sum of the load deformations for all previous load increments. Thus, for the 250th day on the 10 by 10-in. slab, the ratio is 3.2, obtained by dividing 0.000428, the net deformation from the curve, by (0.000076 + 0.000058), the dead-load deformation plus the live-load deformation on the 174th day.

TABLE 4.

Specimen.	Load Deformations.					Ratio: Net Deflection to Load Deflection at:				
	Dead load.	Live load.	Time, in days.	Live load.	Time, in days.	50 days.	100 days.	200 days.	650 days.	950 days.
Beam *A*....	....	0.000280	0	....	...	2.57	2.68	3.39	4.25	4.60
Beam *B*....	0 000200	0.000035	46	0.000075	54	....	2.32	3.11	3.63	3.71
Slab *C*.....	0.000076	0.000058	174	0.000043	275	2.90	....	3.20	4.00	....
Slab *D*.....	....	0.000042	0	0.000065	3	2.24	2.66	3.08	4.11	4.39

Time refers to interval from first application of load.

In the ratios of net to load deformation in Table 4, practically the same values are found as for the corresponding periods in Table 2. The initial moduli for three of these specimens were determined, with the following results:

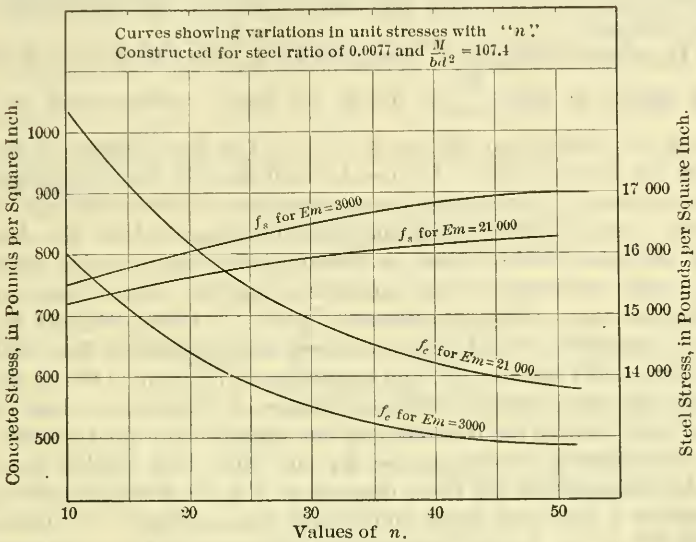
Beam *B*...... 3 460 000 at 27 days.
Slab *C*...... 3 300 000 at 135 days.
Slab *D*...... 2 500 000 at 72 days.

These give values of n ranging from 9 to 12 at the time of application of the loads, from 20 to 30 at 3 months, and from 33 to 53 after 2 years.

The conclusions to be drawn from these tests of shrinkage and time yield, which apply to the question raised by Mr. Jonson, may be summed up as follows: First, in concrete allowed to dry thoroughly a shrinkage of from 0.06 to 0.07% may ordinarily be expected, with a minimum value of 0.05%; second, the modulus of total deformation will be from one-half to one-third of the initial modulus in a few months, and about one-fourth or less after 2 years; that is, on the usual basis of an initial value of n ranging from 9 to 15, values from 20 to 30 may be expected in a few months and from 35 to 60 at 2 years.

Now, to apply the values just quoted for shrinkage and time yield to the calculation of beams in the manner followed by Mr. Jonson, the upper diagram of Fig. 10 has been prepared. The formulas of Mr. Jonson from which this diagram was constructed assume the

Mr. McMillan.



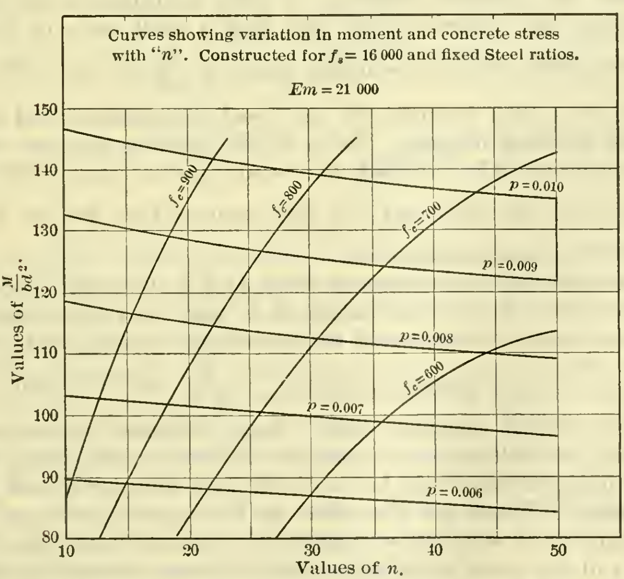


FIG. 10.

Mr. McMillan. condition that the beam is not free to shrink, and therefore the concrete cracks, a condition that may be possible, though probably not the usual one.

The diagram referred to assumes a beam with a steel ratio of 0.0077 and loaded so that $\frac{M}{b\,d^2} = 107.4$, the value corresponding to unit stresses of 16 000 and 650 for $n = 15$. The true stresses in such a beam for various values of n can be read directly from this diagram. The two sets of curves show the extreme cases of shrinkage, the value, 0.01% ($Em = 3\,000$), being the minimum suggested by Mr. Jonson, and the other, 0.07% ($Em = 21\,000$), being the probable ordinary maximum, as shown by the experiments quoted. From these curves it is seen that, with a shrinkage of 0.07%, a beam designed by the usual assumption would have a concrete stress anywhere from 800 for $n = 20$ to 580 for $n = 50$, and a steel stress of from 15 600 to 16 300, within the same limits. For a shrinkage of 0.05% the values would be a little less for the concrete and but slightly more for the steel.

The quantity of steel to use for any unit stress desired can best be determined from the lower diagram of Fig. 10, which has been prepared for a fixed unit stress and several ratios of steel. To illustrate: With 650 as the desired limiting concrete stress and $n = 40$ assumed to represent the probable condition of total deformation, by interpolation from this diagram it is seen that a steel ratio of 0.0085 would be required, with the resulting value of $\frac{M}{b\,d^2}$ at 117. This is 10% more steel than required for the usual assumptions, and gives 9% greater resisting moment. For $n = 30$, the same concrete stress would require only 0.7% of steel, and would give a value of 100 for $\frac{M}{b\,d^2}$; this is 9% less steel and 7% less moment than for the beam designed on the usual assumptions.

Fig. 11 is similar to the lower diagram of Fig. 10, using the value of 3 000 for Em. From this diagram it is seen that, for a concrete stress of 650, 1.2% of steel would be required for $n = 40$, and 1.03% for $n = 30$. The corresponding values of $\frac{M}{b\,d^2}$ are 153 and 138, respectively. When compared with a beam designed by the usual assumptions, the values for $n = 40$ give a beam of 56% more steel and 42% more moment, and for $n = 30$, 34% more steel and 28% more moment. These are the same as the figures given by Mr. Jonson, and, it is seen, show considerably greater variations from the results of the usual calculations than do those obtained by using the higher value for shrinkage. From the tests quoted the higher value seems much more probable, and, therefore, instead of requiring

from 1.03 to 1.20%, as stated by Mr. Jonson, the calculations by his method would be satisfied in all ordinary cases by values ranging from 0.75 to 1.00 per cent. However, as the percentage of increase in cost will be somewhat less than one-half the percentage of increase in steel area, and with the percentage increase in the coefficient of resistance $\left(\frac{M}{b\,d^2}\right)$ nearly as great as that of the steel area, the use of this method will result in a noticeable saving, even with a large shrinkage. Mr. McMillan.

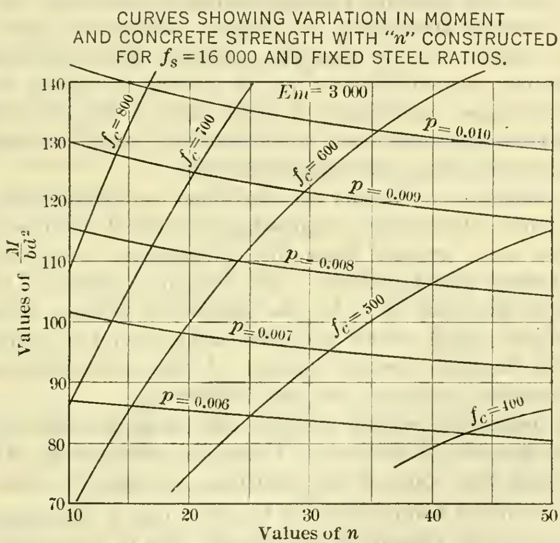


FIG. 11.

The comparisons just presented are interesting in showing possible variation between the results of calculations on the ordinary assumptions and those taking some account of the large non-elastic deformations found to exist. Such calculations, however, are of doubtful value at the present time, except as they may indicate the necessity for a thorough study and revision of the theory of reinforced concrete beams, for they are based on assumptions varying enough from the real conditions to involve greater errors, perhaps, than those they seem to have pointed out. For example, the assumption that the beam is anchored so that the steel does not change in length from the shrinkage is probably not often realized in practice, and, if so, the concrete will probably crack, if at all, at irregular intervals rather than in the manner assumed in the analysis.

Until further knowledge is obtained of the inter-action of the materials under the various conditions that are likely to be encountered

Mr. McMillan. in the completed structure, it does not seem desirable that any change from the present practice in design be attempted; for, as regards the stresses in simply supported beams, as Mr. Jonson has pointed out, the time yielding must result in a readjustment of abnormally high initial concrete stresses. When a revision of the theory is attempted, it must take into consideration, among other things, such conditions as the following: A beam simply supported and free to shrink, with an initial compression in the steel and the concrete uncracked; the same condition with the concrete cracked at rather wide and irregular intervals from the bending moments applied, also with the concrete thoroughly cracked throughout its length. Restrained beams, because of bending cracks over or near the supports, divide themselves into sections which may fulfill any or all of the foregoing conditions. Although all these conditions are neglected in the common theory, they cannot be neglected when an attempt is made to introduce the non-elastic deformations into the calculations.

In the deflection of beams the shrinkage and time yield play an important part. Deflections measured after several months are several hundred per cent. greater than the calculations from the common theory of flexure would indicate. Mr. Jonson's method of calculating deflections, if the value of f_s for the uncracked sections is used, gives results probably much nearer the true value than his moment calculations gives the true stresses, because of the small influences of the occasional tension crack on the total deflection.

It is in regard to column stresses that these non-elastic deformations are of greatest importance. Using the notation of Mr. Jonson, and to re-state here some of his equations, we have the following:

f_r = initial compression in the steel due to shrinkage;
f_i = initial tension in the concrete due to shrinkage;
m = unit shrinkage;
E and n in their usual significance;
f_y = stress in the steel due to the load;
f_x = stress in the concrete due to the load;
f_s = combined steel stress = $f_r + f_y$.
f_c = combined concrete stress = $f_x - f_i$.

$$f_r = \frac{E\,m}{p\,n+1}, \text{ and } f_s = f_y + \frac{E\,m}{p\,n+1} \qquad (1)$$

$$f_i = \frac{E\,m\,p}{p\,n+1}, \text{ and } f_c = f_x - \frac{E\,m\,p}{p\,n+1} \qquad (2)$$

Now, the load applied to the column,

$$P = f_y pA + f_x(A - pA) \qquad (3)$$

in which

$$f_y = f_x\,n \qquad (4)$$

or

$$P = f_x\,A[1 + (n-1)\,p] \qquad (5)$$

Mr. McMillan.

From these formulas can be obtained the actual stresses in columns designed by some of the accepted formulas of the day. For illustration, take two columns using 2% and 4% of vertical steel and 1½% of spirals. Calculated by the Joint Committee recommendations, the values of $\frac{P}{A}$ for these two columns would be 832 and 1 014, respectively. If calculated by the formula and unit stresses permitted in the Minneapolis Building Code:

$$P = 800\,Ac + 10\,000\,As + 2.4 \times 16\,000\,As'$$

the values of $\frac{P}{A}$ are 1 560 and 1 744, respectively.

Applying these formulas to these four columns, we get the actual unit stresses, f_c and f_s, shown in Table 5. These are worked out for two sets of values of Em and n, representing conditions that may frequently be expected.

TABLE 5.

$\frac{P}{A}$	p	$Em = 15\,000$, $n = 40$.				$Em = 21\,000$, $n = 50$.			
		f_x	f_y	f_c	f_s	f_x	f_y	f_c	f_s
832	0.02	467	18 680	300	27 000	420	21 000	210	31 500
1 014	0.04	396	15 840	166	21 600	343	17 150	63	24 150
1 560	0.02	876	35 040	710	43 370	788	39 400	578	49 900
1 744	0.04	682	27 280	450	33 040	590	29 500	310	36 500

From Table 5 it is seen that enormously high steel stresses may be expected in columns as conservatively designed as by the requirements of the Joint Committee, and that in columns in which large allowance is made for the spirals, stresses well above 30 000 lb. cannot be avoided. It should be noted that the shrinkage stress alone in these four columns varies from 6 000 to 10 500 lb. per sq. in. In support of the reasonableness of these calculations, the data on Fig. 12, which shows the results of measurements on columns of two buildings in service, are presented.

In the first building the columns were 5 months old, and were carrying four floors and the roof when the observations were begun. Only a small quantity of dead load, such as partitions, interior finish, and equipment, has been added since. This is a university building, and, like others of its class, receives a very small proportion of the live load for which it was designed. The results of these observations are given in the curves marked Column 1 and Column 2. These measurements were made at the surface of the column, but it is believed

Mr. McMillan. that measurements taken directly on the vertical rods would have shown the same results. The steel stress represented by these deformations is 18 000 lb. per sq. in., which is very noteworthy when it is considered that practically no dead or live load is included, and that at least some of the shrinkage must have taken place during the 5 months before the gauge lines were established.

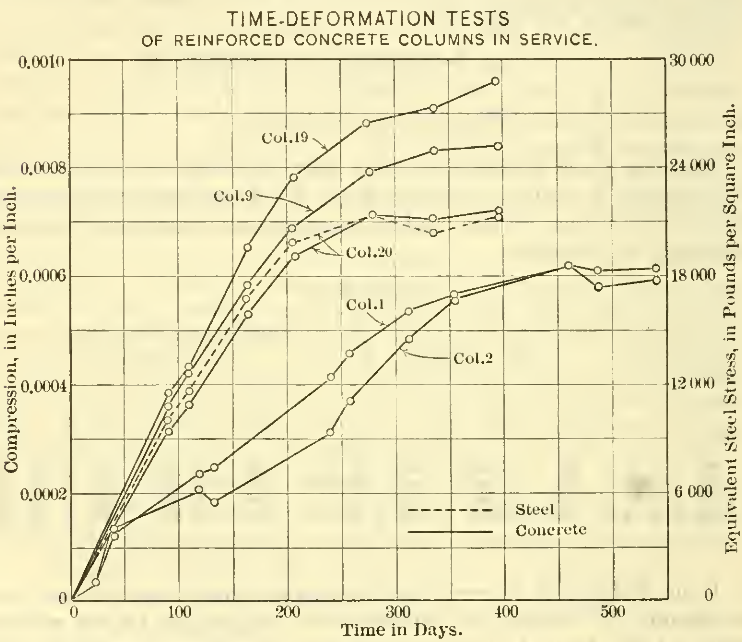


FIG. 12.

The observations on the second building are given in the curves for Columns 9, 19, and 20. These were begun when the columns were about 2 months old, and were carrying only a portion of the full dead load; the results, therefore, probably show a considerable portion of the shrinkage, as well as some of the dead-load stress. Like the previous building, very little live load comes to these columns, although it is provided for in the design. For Column 20, observations on both the concrete at the surface and on the vertical steel are shown; these, it will be noted, are in practical agreement. The steel stresses from the measurements on these three columns are from 21 000 to 28 000 lb. per sq. in., with the indication that there may be still some increase. These are basement columns, and as yet they have not been thoroughly dried out.

These measurements on columns under the conditions of ordinary construction, showing steel stresses ranging from 18 000 to 28 000 lb., where only a part of the load and shrinkage are included, seem to the writer to be satisfactory experimental verification of the calculations of column stresses based on the values of time yield and shrinkage taken from the other tests quoted. When columns designed by the methods of common practice show such high steel stresses as these calculations and tests indicate, there seems to be little to warrant the continuance of such a practice. Though the writer does not advocate any change in the practice of the design of reinforced beams, until a thorough revision of the theory of flexure is possible, he believes that in the case of columns a change is imperative. Mr. McMillan

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

AMORY COFFIN, M. Am. Soc. C. E.*

DIED JUNE 5TH, 1916.

Amory Coffin, the eldest son of Dr. T. C. Amory Coffin and Jessie M. (Edmondston) Coffin, was born in Charleston, S. C., on August 9th, 1841. He received his early education at a military school in Yorkville, S. C., and, later, entered the South Carolina Military Academy, known as the "Citadel", at Charleston, from which he was graduated in 1862.

Mr. Coffin was in command of the squad which fired what was practically the first gun of the Civil War, namely, an alarm gun to notify the batteries around Charleston that the U. S. Steamer *Star of the West* had been sighted farther up the coast, bound for the relief of Fort Sumter.

During the war he was engaged most of the time in and around Charleston with a battery known as the Washington Artillery. In one of the larger skirmishes, while acting as Adjutant, he was severely wounded in the head and disabled for several months.

After the close of the war Mr. Coffin secured such employment as was available in that unhappy region, teaching school, surveying, and, with his father, even translating into English the German novel, "Merchant of Berlin", by Mühlbach.

In 1867 he was engaged by the Phœnix Iron Company, at Phœnixville, Pa., in making designs and estimates on iron structures. He made a survey of the plant of the Company and of a large part of the Town of Phœnixville, and designed most of the mills and shops there. Mr. Coffin edited the handbook of the Company, which was the first of its kind and has been so generally copied by all makers of structural shapes. The graphical table showing the values of beams for various spans and floor loads was originated and copyrighted by him in 1885.

He had an exceedingly fine sense of the proper proportion in all things, and was most painstaking to secure the best results. His designs for the rolls with which the Company made the various sections remained unchanged until the Standard Sections, now in general use, were adopted, and from which they differ but slightly.

In November, 1885, Mr. Coffin became Chief Engineer of the Phœnix Iron Company and remained in that capacity until March, 1896. He designed the structural features of many of the notable

* Memoir prepared by T. Amory Coffin, M. Am. Soc. C. E.

buildings of that period, among them being Madison Square Garden, New York, the Crocker Building, San Francisco, which was provided with earthquake bracing, the Provident Life and Trust Company Building, Philadelphia, the Equitable Building, Baltimore, and numerous buildings for the Government in Washington in connection with the Supervising Architect's office.

In 1896, Mr. Coffin moved to New York City to take charge of the engineering work of the well-known architect, the late George B. Post, M. Am. Soc., C. E., with whom he was associated until 1909.

During this period many buildings of considerable importance came under Mr. Coffin's supervision, among them being the St. Paul Building, New York, and the New York Stock Exchange, where many exacting conditions of structure and foundation were successfully met.

He prepared the engineering designs for the College of the City of New York, the Prudential Life Insurance Company buildings and the Mutual Benefit Building in Newark, N. J., the Vincent Building, New York City, and the Wisconsin State Capitol, at Madison. In the design of the steelwork for the Williamson Building, Cleveland, Ohio, he utilized the features of the then popular Z-bar column to economize on the floor system and column design by allowing the girders to pass through the columns on their central axes, thus securing the benefits of cantilever construction and central column loading.

Mr. Coffin also was Consulting Engineer for Messrs. Phelps, Dodge and Company on the bridge at El Paso, Tex., and for several other bridges on the line of the El Paso and Southwestern Railway.

He was of a quiet and retiring disposition, and spent most of his time with his family and his friends. Those who knew him, either in a business or social way, always found him affable and kind; for him it was never any trouble, but rather a delight, to give the fullest explanation possible on any subject, and his friends often availed themselves of his great store of information, gathered by a life of study and of experience and put to the fullest possible use. For several years Mr. Coffin was President of the Board of Health of Phœnixville, and a Trustee of the Phœnixville Library.

On January 14th, 1868, he was married to Emma Hopkinson, of Edisto Island, S. C. In 1912, he returned to Phœnixville where he resided until the death of his wife, on February 15th, 1916. On account of his failing health, it became necessary to seek a more suitable climate, and in March of that year he moved to the home of his son, Francis H. Coffin, at Scranton, Pa., where, after several recoveries and relapses, he finally passed away on June 5th, 1916.

He is survived by three sons, Thomas Amory Coffin, M. Am. Soc. C. E., Francis Hopkinson Coffin, and Laurence Edmondston Coffin.

Mr. Coffin was elected a Member of the American Society of Civil Engineers on March 3d, 1875.

ASA BETTS FITCH, M. Am. Soc. C. E.*

Died March 11th, 1916.

Asa Betts Fitch, the eldest son of Charles and Elizabeth Marilla (Betts) Fitch, was born on a farm near Ellsworth, Ohio, on June 17th, 1840. He was a lineal descendant of Thomas Fitch, the Colonial Governor of Connecticut under King George III.

In 1847, his parents removed to Woodstock, Ill., where he studied at public and private schools until 1857, when the family removed to Stacyville, Iowa. In this new country advanced educational facilities were lacking, and during 1858 and 1859, Mr. Fitch worked on the farm during the summer and taught country schools in the winter. In 1860, he taught school at Mitchell, Iowa, and prepared for college with a private tutor.

The call to arms in the Civil War, however, over-ruled, in his mind, all private affairs, and he volunteered. He took part in raising a company at Stacyville, Iowa, in which he enlisted as private, becoming First Sergeant on its organization. This company became H in the Fourth Iowa Cavalry, in which regiment he was in active service in the field until the end of the war, serving in many engagements in Missouri, Kansas, Arkansas, Mississippi, and Alabama, and never off duty. He was wounded in action in command of his company at Marianna, Ark., was rapidly promoted until he became Captain, and was recommended for promotion to Brevet-Major by his Brigade, Division, and Corps Commanders "for great gallantry" in battle. During the last year of the war, Captain Fitch was detached as Aide and then as Acting Assistant Quartermaster-General on the staff of General Winslow, commanding brigade and division.

Among the many campaigns in which he was engaged were those in which Vicksburg was taken, Price's army was destroyed in Missouri and Kansas, Forrest was defeated in Mississippi, and Wilson's column of cavalry swept through Alabama and Georgia, the greatest and most successful cavalry campaign in history.

Captain Fitch was an ideal soldier—tall, straight, of fine military bearing; decided in speech, yet of few words; careful of his men yet keeping his hand sternly on the reins of duty; bold yet not reckless; always ready for orders and instantly zealous in their execution. If he had chosen a military career, he must have become an admirable soldier and a distinguished commander.

At the end of his military service, Captain Fitch decided that he was too old to enter college, but this did not alter his determination

* Memoir prepared by the Secretary from information furnished by the family and on file at the Society House.

to become a Civil Engineer, although this decision meant an uphill course of study and practical work at the same time, and resulted in his being a student all his life.

Having suffered much from malaria during the last year of his Army service and being unfit for work, he spent the summer and winter of 1865-66 in visiting relatives in New Hampshire and hunting in Northern Iowa.

In the spring of 1866, Captain Fitch entered the employ of the National Express Company in Cincinnati, Ohio, as "Route Agent", under his old Commander, General Winslow. With the idea of carrying out his plan of becoming a Civil Engineer, however, he applied to the late Grenville M. Dodge, Hon. M. Am. Soc. C. E., Chief Engineer of the Union Pacific Railroad, then being commenced, for a position with the Engineering Corps. Gen. Dodge appointed him Division Engineer of the road in Nebraska, but, after consideration, Captain Fitch declined the appointment to go with Gen. Winslow on the Vandalia Railroad then being projected. Work on this road was begun in the Spring of 1867, and Captain Fitch continued in the employ of the Company under Col. Carswell McClellan and the late E. C. Rice, M. Am. Soc. C. E., until the road was purchased by the Pennsylvania Railroad Company in 1869, having been promoted from Chainman to Assistant Engineer.

Captain Fitch then entered the service of the Evansville, Terre Haute and Chicago Railroad Company as Transitman on preliminary survey and location, and, in 1870, when construction was begun, he was put in charge of a division of 22 miles, which included a bridge across the Wabash River, at Clinton, Ind. When the road was completed and opened in 1871, he was made Chief Engineer, Roadmaster, and Paymaster. He retained these positions, planning the yards, shops, etc., at Danville, Ill., and Terre Haute, Ind., laying out short branch lines to coalfields, etc., until early in 1873 when he leased 80 acres of coal lands east of the Wabash River, near Clinton, Ind. For a year the enterprise proved successful, but the financial panic and strikes of that period made the situation desperate for the owners, and to control competition, Captain Fitch organized a combination of all the Clinton mines, of which he became President and Sales Agent. After five years of exacting labor, he accepted an offer for his entire coal interests which left him without any reward for his work. During this strenuous period he had also laid out and supervised the construction of 4 miles of gravel road running west from Clinton, which was a marked success and attracted much attention among road builders throughout the State of Indiana.

In 1878, Captain Fitch served one term as City Engineer of Terre Haute, Ind., and in that capacity built sewers and gravel streets,

re-surveyed the City, and marked the streets with permanent monuments.

In 1879, after building a bridge over White River on the Evansville and Crawfordsville Railroad, he was appointed Chief Engineer of the Terre Haute and Southeastern Railroad, which position he retained for nearly two years. He located and built an extension of 14 miles from Clay City to Worthington, Ind., extended the road to connections with other roads in Terre Haute, and built several short branches to coal mines in the vicinity.

Late in the summer of 1880, Captain Fitch was made Chief Engineer on the extension of the Terre Haute and Logansport Railroad from Logansport to South Bend, a distance of 67 miles, and it was on this work that his reputation as a Location Engineer of much more than average ability, was made.

Before the completion of his work on the Logansport Extension, he was appointed Superintendent of Construction of the Government Building at Terre Haute, Ind., but a political change at Washington compelled him to resign before he had completed the work.

During 1885 and until the autumn of 1886, Captain Fitch was engaged in a survey for 8 miles of railroad through the coalfields of Illinois; on a report on a railroad site and coalfield in the Black Hills of South Dakota; and on an investigation of gold and silver mines in Mexico, for various financial interests.

During the college term of 1886-87, he occupied the Chair of Civil Engineering at Rose Polytechnic Institute, taking the place of a professor who had resigned just before the term began. Although without college training himself, he was very successful in this work and was urged to continue it, but he declined, and late in 1887, he was engaged to re-measure some heavy rock excavation on the Nashville and Knoxville Railroad in Tennessee. In 1888, he was made Chief Engineer of that road, building the bridge across the Caney Fork of the Cumberland River and completing the road to Cookville.

During the winter of 1888-89, Captain Fitch made an examination and estimate for the completion of 80 miles of railroad from New Castle, Pa., to Akron, Ohio, for some New York financiers. Early in 1889, he returned to the Mission Coal Field in Indiana, in which he had never quite lost his early interest, and obtaining options for the purchase of the lands covering those fields, he made plans and estimates for a railroad to tap that region. He submitted all the data to the General Manager of the Illinois Central Railroad and while the officials of that road were considering the proposition, Captain Fitch went to Texas and made an examination and report on an extension of the Austin and Northwestern Railroad from Burnet to Granite Mountain, which was afterward constructed. On his

return to Indiana, he found that the Illinois Central had decided not to use his plans, and, his options on the Mission Coal Field having about expired, he sold them to the Consolidated Coal Company of St. Louis, Mo., and that Company afterward developed the field on his plans.

In 1889, after making a preliminary survey for a railroad up the valley of Green River, from Henderson to Bowling Green, Ky., about 100 miles (which was never built), Captain Fitch went to Nevada, in the interests of some New York investors, to report on a coal property. This work was followed by reconnaissances for the relocation of the Terre Haute and Indianapolis Railroad in the vicinity of Rockville, Ind., and also for the Vandalia Line, both of which were afterward built.

Early in 1890, Captain Fitch went to Chattanooga, Tenn., to examine and report on coal land in Southern Tennessee, and remained to take charge of various financial projects for Mr. Jere Baxter, of Nashville, Tenn. Among these projects were the management of Lookout Inn, a railroad running from the city to the Inn, a coalfield on Lookout Mountain, and a Belt Railroad around Chattanooga. He was very successful in the management of these interests, but preferred engineering, and after Mr. Baxter's return, Captain Fitch went to Florida to study the occurrence and working of phosphate deposits in that State.

In the fall of 1890, he went to Salt Lake City, Utah, to examine and report on the Utah Central Railroad for English financiers. In 1891, Captain Fitch examined and located an extension of the Danville, Olney and Ohio Railroad from Sidell to Chicago, with an estimate of the cost, for some promoters, but the scheme failed.

In the latter part of 1891, he was asked to report on some vitrified brick paving contracts which had been made by the Common Council of Terre Haute, by a Committee which was investigating the matter, and after much persuasion, Captain Fitch was prevailed on to accept the appointment of City Engineer and finish the work. At this time vitrified brick paving was a novelty, and as there were no standards to work by, he had to "blaze the way". His work was successful, but as soon as it was completed he resigned.

In 1893, Captain Fitch went to Magdalena, N. Mex.; to erect hoisting machinery in the Graphic Mine at that place, for Terre Haute and Philadelphia promoters. He expected to remain only a few weeks, but stayed eleven years, removing his family there in December, 1896. After developing the property, he, in June, 1896, leased the entire plant, built a smelter for his ore, and a tram-road to the mine. In the summer of 1902 the ore in the property was apparently exhausted, and the smelter was shut down. After many financial and legal vicissi-

tudes, in the summer of 1903, replacement ore was discovered. This increased greatly the value of the Graphic property, and, on March 30th, 1904, it was sold to the Sherwin-Williams Paint Company, of Cleveland, Ohio, and Captain Fitch removed his family to California.

In 1905, they settled in Hollywood, where Captain Fitch organized the Temescal Rock Company of which he was President and Manager until his death on March 11th, 1916.

He was married on January 15th, 1868, to Miss Amelia Pauline Grimes, the daughter of James and Mary Ann (Tobin) Grimes, old and prominent residents of Portsmouth, Ohio, and she, with four sons and three daughters, survives him.

Captain Fitch was peculiarly a home body, loving his home and family, and only his intimate friends knew the broad scope of his information, his splendid mental poise, his rare executive ability, his kindly management of men, and his genial nature.

He was a member of the Masonic Fraternity, the Loyal Legion, and of St. Stephen's Protestant Episcopal Church, of Hollywood, Cal.

Captain Fitch was elected a Member of the American Society of Civil Engineers on March 6th, 1884.

FREDERIC CHARLES KUNZ, M. Am. Soc. C. E.*

Died May 3d, 1916.

Frederic Charles Kunz was born in Prague, Austria, on January 19th, 1862, and completed his technical studies at the Polytechnical School in that city, from which he was graduated in 1886. He spent the next 5 years in the service of the Austrian Northern (Kaiser Ferdinand) Railroad, as Assistant Engineer on important construction work, comprising about 200 miles of new lines. Young as he was, he already showed such conspicuous ability, that he was also given charge of the construction of iron and masonry bridges.

In the summer of 1891, Mr. Kunz came to the United States and found employment as Assistant Engineer in the Bridge and Construction Department of the Pencoyd Iron Works, in Philadelphia, Pa. He remained with this Company, except for the period from 1893 to 1896, during which he was engaged in designing steel and masonry bridges in the Bureau of Surveys, Department of Public Works of Philadelphia, until it was absorbed by the American Bridge Company. He then became Assistant to the late C. C. Schneider, Past-President, Am. Soc. C. E., the Vice-President and Chief Engineer of that Company, with whom he remained until the summer of 1903.

* Memoir prepared by Gustav Lindenthal, M. Am. Soc. C. E.

The most important work on which Mr. Kunz was engaged during his connection with the Pencoyd Iron Works was the working up of the erection plans for the Clifton Arch Bridge for highway traffic, immediately below Niagara Falls. This bridge was designed by the late L. L. Buck, M. Am. Soc. C. E., the Pencoyd Iron Works being the contractors. Mr. Kunz had also much to do with the checking of the strain sheets and details of construction, and afterward of laying out the system of erection, which had many novel and difficult features.

Later in 1903, he was appointed by the writer, at that time Commissioner of Bridges of New York City, to the position of Consulting Engineer of the Bridge Department, where he took an active and important part in the preparation of the specifications and plans for the Manhattan Bridge and the Queensborough Bridge. Early in 1904, he resigned to become Chief Engineer of the Bridge Department of the Pennsylvania Steel Company, in Steelton, Pa., where he remained for several years.

The most prominent work of which Mr. Kunz had charge during this period was the fabrication of the Queensborough Bridge. When, in 1908, the safety of this bridge became a subject of controversy, he wrote a comprehensive report on it. During his connection with the Pennsylvania Steel Company, he designed a large number and variety of railroad bridges which were fabricated in Steelton. It was at this time that he commenced to write his book on "Design of Steel Bridges", for which he had accumulated data and material for many years previously.

His last construction work was the steel arch highway bridge at St. Johns, New Brunswick, over the St. Johns River, which was built to replace an old wire suspension bridge at the same place. In the preparation of these plans, he was associated with his friend, Mr. C. C. Schneider, whom he followed in death within 4 months.

The personal and professional life of Mr. Kunz, was simple and unostentatious and although an engineer of exceptional capacity and attainments in his particular branch, steel bridge engineering, he was not as widely known as his worth deserved, because of his innate modesty. His name, however, will remain known to bridge engineers through his work on "Design of Steel Bridges", in which he perpetuated his fine analytical mind, as well as his practical experience. His book is not only a valuable gift to the bridge specialist, but an honor to the Profession at large, which esteems and appreciates engineering ability of high quality.

To those who enjoyed Mr. Kunz's intimacy and friendship, he will remain unforgotten through his charming and pleasant personality. A great fund of wit, a wide range of reading, a love of higher

music, a deep sense of right, and a philosophic wisdom in human affairs, made conversation and social intercourse a privilege and pleasure to those of his friends to whom he chose to unbosom himself.

Mr. Kunz's health had been poor for several years, and it is deplorable that such a useful life as his should have been cut short by his untimely death. He left no relatives in this country, but is survived by a son and a nephew who live abroad.

Mr. Kunz was elected an Associate Member of the American Society of Civil Engineers on February 6th, 1895, and a Member on December 7th, 1898.

ERNEST FREDERICK TABOR, M. Am. Soc. C. E.*

Died August 20th, 1916.

Ernest Frederick Tabor was born at Worcester, Mass., on February 26th, 1866. In his youth, his parents moved to California, where he received his education in the public schools and at the University of California.

At the age of 21, Mr. Tabor began his engineering career, in the office of the San Diego Flume Company, and was connected in various engineering capacities with a number of large enterprises in Southern California. In 1890 he made the preliminary investigations for the Escondido Irrigation District, and in 1894-95, as Chief Engineer, he had charge of the construction of the Escondido Dam, a rock-fill structure of note, which has been described in many engineering papers. He also had charge of the construction of canals and pipe lines to reach about 3 000 acres of settlers' lands.

During 1900 Mr. Tabor was engaged in the location and construction of a 20-mile, wood-stave pipe from the Lower Otay Reservoir to San Diego. This work included several tunnels and an earth dam. Mr. Tabor's general engineering practice in Escondido, Cal., included work on street grades and water-works for the Towns of Escondido, Elsinore, and San Jacinto, Cal. In 1902, he had charge of the operation of the works of the Escondido Irrigation District, but resigned later to take up similar work with the Sweetwater Water Company, at National City, Cal.

In 1904, Mr. Tabor resigned his position with the Sweetwater Water Company to enter the service of the United States as Assistant Engineer in the Reclamation Service, and after 6 months he was appointed Engineer. The next three years were spent on assignments on the Shoshone Project, Wyoming, where his principal work was the loca-

* Memoir prepared by A. P. Davis, M. Am. Soc. C. E.

tion and construction of the Garland Main Canal and some of its principal laterals. He was then placed in charge, as Project Manager, of an irrigation project on the Flathead Indian Reservation, with headquarters at St. Ignatius, Mont., which position he held until his death. The work there was of a pioneer character, and included topographical surveys and studies of stream flow, followed by surveys and formulation of plans for serving about 150 000 acres of irrigable land, and using the flow of about sixty small streams for this purpose, making a very complicated system. Mr. Tabor considered the development of these plans the most difficult and important work he had ever undertaken. While in charge of the Flathead work, he was also occasionally called on for consultation regarding the principal canals on the Blackfeet, Milk River, Shoshone, and Sun River Projects, of the Reclamation Service, as he was considered an expert specialist in canal location and construction.

Mr. Tabor died at St. Ignatius, Mont., from peritonitis.

On May 10th, 1893, he was married to Miss Gertrude M. Smith, who, with two children, survives him.

Mr. Tabor was elected a Member of the American Society of Civil Engineers on May 1st, 1907.

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"A METHOD OF DETERMINING A REASONABLE SERVICE RATE FOR MUNICIPALLY OWNED PUBLIC UTILITIES." J. B. LIPPINCOTT. (To be presented Oct. 18th, 1916.)

"A COMPLETE METHOD FOR THE CLASSIFICATION OF IRRIGABLE LANDS." F. H. PETERS. (To be presented Nov. 1st, 1916.)

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ON MATERIALS FOR ROAD CONSTRUCTION: W. W. Crosby, A. W. Dean, H. K. Bishop, A. H. Blanchard, George W. Tillson, Nelson P. Lewis, Charles J. Tilden.

ON VALUATION OF PUBLIC UTILITIES: Frederic P. Stearns, Charles S. Churchill, Leonard Metcalf, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus.

TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS: Nelson P. Lewis, S. L. F. Deyo, Dugald C. Jackson, William V. Judson, George W. Tillson, C. F. Loweth, John A. Bensel.

TO CODIFY PRESENT PRACTICE ON THE BEARING VALUE OF SOILS FOR FOUNDATIONS, ETC.: Robert A. Cummings, Edwin Duryea, Jr., E. G. Haines, Allen Hazen, James C. Meem, Walter J. Douglas.

ON A NATIONAL WATER LAW: F. H. Newell, W. C. Hoad, John H. Lewis.

TO REPORT ON STRESSES IN RAILROAD TRACK: A. N. Talbot, A. S. Baldwin, J. B. Berry, G. H. Bremner, John Brunner, W. J. Burton, Charles S. Churchill, W. C. Cushing, Robert W. Hunt, George W. Kittredge, Paul M. LaBach, C. G. E. Larsson, G. J. Ray, Albert F. Reichmann, H. R. Safford, F. E. Turneaure, J. E. Willoughby.

The House of the Society is open from 9 A. M. to 10 P. M. every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

HOUSE OF THE SOCIETY—220 WEST FIFTY-SEVENTH STREET, NEW YORK.

TELEPHONE NUMBER........................1446 Circle.
CABLE ADDRESS......................"Ceas, New York."

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

SOCIETY AFFAIRS

CONTENTS

MINUTES OF MEETINGS

OF THE SOCIETY

September 20th, 1916.—The meeting was called to order at 8.30 P. M.; J. Waldo Smith, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 202 members and 39 guests.

A paper by Israel V. Werbin, Assoc. M. Am. Soc. C. E., entitled "Tunnel Work on Sections 8, 9, 10, and 11, Broadway-Lexington Avenue Subway, New York City", was presented by the author and illustrated with lantern slides.

A communication on the subject by Maurice Griest, Esq., was read by the Secretary, and the paper was discussed by Messrs. T. Kennard Thomson, John H. Madden, Robert H. Jacobs, John H. Myers, H. G. Moulton, W. J. Boucher, Robert Ridgway, C. V. V. Powers, and the author.

The Secretary announced the election of the following candidates on September 12th, 1916:

As Members

James Murray Boyle, New York City
John Lafayette Brower, Toronto, Ont., Canada
John Ryan Burke, Boston, Mass.
John Carson, Duluth, Minn.
Louis Reno Cobb, New York City
Edward Kirk Coe, Duluth Minn.
Joachim Gotsche Giaver, Chicago, Ill.
Meier George Hilpert, Harrisburg, Pa.
William Horatio McAlpine, Louisville, Ky.
George Bragg Massey, Chicago, Ill.
Arthur Page Noyes, San Francisco, Cal.
Chester Nelson Reitze, Seattle, Wash.
William Lincoln Rockwell, San Antonio, Tex.
Arturo Rodriguez, Ithaca, N. Y.
Ernest George Schurig, Lincoln, Nebr.
Fenwick Fenton Skinner, New York City
Milton Theodore Thompson, New York City
Miguel Triana, Bogota, Colombia
William Gordon Woolfolk, Chicago, Ill.

As Associate Members

John Waddington Harry Barnes, Madera, Cal.
John Arthur Beemer, Boise, Idaho
Charles Renwick Breck, Jr., Anchorage, Alaska
Howard Edward Burns, St. Louis, Mo.
Charles Albert Cummins, Baltimore, Md.
Thomas Austin Currie, Jr., Boston, Mass.
Charles Henry Dading, Philadelphia, Pa.
William Edward Dawson, Dubuque, Iowa
William Driscoll, Guantanamo, Cuba
Allen Douglas Duck, Greenville, Tex.
Philip Norrison Fawcett, Tientsin, China
Victor Leroy Fixen, St. Paul, Minn.
Alexander Vincent Gallogly, New York City
William Richard Gelston, Quincy, Ill.
William Albert Grover, Dover, N. H.
John Lechmere Guppy, Port of Spain, Trinidad
Herman Henry Hanink, Palos Park, Ill.
Harlan Tylee Hare, Duluth, Minn.
Carl James Herbold, Cleveland, Ohio
George Martin Hopkinson, New York City

John Spence Howard, Baltimore, Md.
Arthur David Hyman, New York City
Nathan Clarke Johnson, New York City
Edward Lindley Jones, Evanston, Ill.
Earl Foster Kelley, Ames, Iowa
Percy Mapes Lau, Detroit, Mich.
Alexander Ross Leckie, Dallas, Tex.
Leon Roderick Mackenzie, Chicago, Ill.
John Joseph McCabe, Troy, N. Y.
William Lamson McCarty, Santo Domingo, Dominican Republic
Carl Arthur McClain, Emerson, Iowa
Erwin Maerker, Jackson, Mich.
William Whipple Michael, Wallkill, N. Y.
Jewett Beach Newton, Boston, Mass.
Albert Colwell Norton, Denver, Colo.
Solomon Reswick, Utica, N. Y.
Fred Denniston Sayer, Brookville, Pa.
John George Schmidt, Norwood, Ohio
John Rockwood Sherman, Meadow Creek, Wash.
Benjamin Alvan Sleeper, Camden, N. J.
Clark Dee Sniggs, Manila, Philippine Islands
Burt Stimson, Seattle, Wash.
Arthur Ducat Stivers, Pittsburg, Tex.
Horace Stringfellow, Alexandria, Va.
Joseph C. Thoma, Salt Lake City, Utah
Martin Wilhelm Torkelson, Madison, Wis.
Kells Emmett Traylor, Winona, Miss.
Winslow Barnes Watson, Albany, N. Y.
Wilfred Ashenhurst White, Portland, Ore.
Rudolph James Wig, Washington, D. C.

As Associates

Albert Farwell Bemis, Boston, Mass.
Howard Emerson Church, Springfield, Mass.
Edward Kimball Fenno, Syracuse, N. Y.
Roy Artimus Manwaring, Philadelphia, Pa.
William Lewis Stancliffe, New York City

As Juniors

Harry Samuel Andrews, Jackson, Tenn.
Clifford Aull Betts, Mariel, Cuba
Kendal Benjamin Bragg, Dayton, Ohio
George Dashiell Camp, Boston, Mass.

James Leslie Cheatham, New York City
Donald Gladstone Coombs, Meadow Creek, Wash.
Alberto Dupuy, Bogota, Colombia
Benjamin Hurt Hardaway, Jr., Whitney, N. C.
Walton Harrington, Newark, N. J.
Gerald Branch Howard, Nashville, Tenn.
William Clark Irwin, St. Louis, Mo.
Francis Whittier Johnson, New York City
Philip Wheeler Kniskern, Chicago, Ill.
Edward Aloysius Short, Grand Mere, Que., Canada
Ray Newhall Spooner, Brooklyn, N. Y.
Maximilian Steinberg, New York City
George Albert Tilton, Jr., Los Angeles, Cal.
Lloyd Woolsey Weed, New York City
Wendell Howard Woolworth, Hanover, N. H.

The Secretary announced the transfer of the following candidates on September 12th, 1916:

From Associate Member to Member

Irving Clinton Brower, Evanston, Ill.
Ralph Haney Burke, Chicago, Ill.
Camden Page Fortney, Pilcher, Ky.
William Isaac Nolen, Copperhill, Tenn.
William Watters Pagon, Baltimore, Md.
Charles Victor Seastone, Madison, Wis.
Ira Otis Thorley, Denver, Colo.
Howard Moore Turner, Turners Falls, Mass.
Achille Octave Van Suetendael, Albany, N. Y.

From Junior to Associate Member

Harold Eaton Babbitt, Urbana, Ill.
Herbert Scandlin Battie, Atlanta, Ga.
William Blair Bovyer, San Francisco, Cal.
Charles Frederick Breitzke, Boonton, N. J.
Carlyle Hugo Bryson, Lima, Ohio
Antonia Castillo y Grau, Cienfuegos, Cuba
Howard Foster Clark, San Francisco, Cal.
John Russell Derrick, Bluefield, W. Va.
William Bullard Durant, Turners Falls, Mass.
Arthur Ludwig Enger, Tucson, Ariz.
Edgar Dow Gilman, Minneapolis, Minn.
Stuart Chapin Godfrey, West Point, N. Y.
Peter Davidson Gunn Hamilton, Needham, Mass.
Charles Royce Hauke, Harlem, Mont.

Frank Ray Howe, New York City
Edwin Hall Marks, West Point, N. Y.
William Grover Morrison, Des Moines, Iowa
Alexander Stuart Russell, Richmond, Cal.
Carl William Schedler, Jr., Pittsburg, Cal.
Hymen Aaron Seltzer, St. Louis, Mo.
Peter Soo-Hoo, Canton, China
George Ernest Strehan, New York City
James Arthur Thompson, New York City
Frederick Williams, New London, Conn.
Alfred Daniel Wolff, Jr., Poughkeepsie, N. Y.

The Secretary announced the following deaths:

Richard Parkhurst Bloss, of Mechanicsville, N. Y., elected Member, January 6th, 1904; died May 22d, 1916.

Charles Adolphus Caldwell, of Macon, Ga., elected Member, September 5th, 1911; died August 31st, 1916.

Adjourned.

October 4th, 1916.—The meeting was called to order at 8.30 P. M.; Director Arthur S. Tuttle in the chair; Chas. Warren Hunt, Secretary; and present, also, 141 members and 23 guests.

The minutes of the meeting of September 6th, 1916, were approved as printed in *Proceedings* for September, 1916.

A paper by H. de B. Parsons, M. Am. Soc. C. E., entitled "Underpinning Trinity Vestry Building for Subway Construction", was presented by the author and illustrated with lantern slides. A communication on the subject from J. C. Meem, M. Am. Soc. C. E., was read by the Secretary, and the paper was discussed by Messrs. T. Kennard Thomson, James F. Fouhy, Charles Rufus Harte, Joseph A. A. Connelly, J. S. Branne, A. W. Buel, and the author.

The Secretary announced the following deaths:

Frank McMillan Stanton, of New York City, elected Member, February 1st, 1899; died September 11th, 1916.

Robert Hammond Boynton, of Frankfort, Ind., elected Junior, May 6th, 1914; Associate Member, April 18th, 1916; died September 18th, 1916.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

November 1st, 1916.—8.30 P. M.—A regular business meeting will be held, and a paper by F. H. Peters, Assoc. M. Am. Soc. C. E., entitled "A Complete Method for the Classification of Irrigable Lands", will be presented for discussion.

This paper was printed in *Proceedings* for September, 1916.

November 15th, 1916.—8.30 P. M.—At this meeting a paper by Charles A. Ferry, M. Am. Soc. C. E., entitled "The Yale Bowl", will be presented for discussion.

This paper is printed in this number of *Proceedings.*

LIST OF NOMINEES FOR THE OFFICES TO BE FILLED AT THE ANNUAL ELECTION, JANUARY 17th, 1917

The list of nominees for the offices to be filled at the Annual Meeting, January 17th, 1917, was received from the Nominating Committee. The nominee for the office of President, having declined the nomination, the Board of Direction, at its meeting on October 10th, 1916, selected a nominee, completing the list in accordance with Art. VII, Sec. 3, of the Constitution. The list has already been mailed to all Corporate Members:

For President to serve one year:

George H. Pegram, New York City.

For Vice-Presidents to serve two years:

George W. Kittredge, New York City.

George S. Webster, Philadelphia, Pa.

For Treasurer to serve one year:

George W. Tillson, Brooklyn, N. Y.

For Directors to serve three years:

Alfred D. Flinn, New York City	District No. 1
Lewis D. Rights, New York City	District No. 1
William R. Hill, Albany, N. Y.	District No. 3
Arthur P. Davis, Washington, D. C	District No. 5
W. L. Darling, St. Paul, Minn	District No. 7
R. H. Thomson, Seattle, Wash	District No. 12

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

President, H. L. Haehl; Secretary, E. T. Thurston, 57 Post Street, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary.

Colorado Association, Organized 1908.

President, Thomas W. Jaycox; Secretary-Treasurer, L. R. Hinman, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

June 10th, 1916.—The Eighth Annual Meeting was called to order at The Denver Athletic Club; President John E. Field in the chair; L. R. Hinman, Secretary; and present, also, 30 members and 25 guests.

The minutes of the meeting of May 13th, 1916, were read and approved.

President Field presented an address on "The Engineer in the Business World".

The Reports of the Secretary-Treasurer, the Auditing Committee, and the Nominating Committee, were presented. On motion, duly seconded, the reports were accepted and ordered placed on file, and the Committees were discharged.

Messrs. W. L. Reynolds, C. S. Lambie, and R. W. Toll were appointed Tellers to canvass the ballots for officers for 1916-17.

Mr. T. B. Stearns addressed the meeting on the work of the Local Committee in connection with the National Industrial Preparedness Board.

The Secretary read the resolutions adopted by the Baltimore Association in the matter of appropriations for the use of the Maryland Board of Directors on Industrial Preparedness.

Attorney-General Farrar, State of Colorado, addressed the meeting, commenting on statements made by President Field in his address.

The Secretary announced the purchase of a stereopticon for the use of the Association.

On the report of the Tellers, the following officers were declared elected: President, Thomas W. Jaycox; Vice-President, Robert Follansbee; Secretary-Treasurer, L. R. Hinman.

J. B. Lippincott, M. Am. Soc. C. E., presented a paper on "The Construction and Operation of the Los Angeles Aqueduct", illustrating his remarks with lantern slides. A vote of thanks was tendered Mr. Lippincott for his interesting paper.

Adjourned.

Atlanta Association, Organized 1912.

President, Paul H. Norcross; Secretary-Treasurer, Thomas P. Branch, Georgia School of Technology, Atlanta, Ga.

The Association holds its meetings at the University Club, Atlanta, Ga. Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

Baltimore Association, Organized 1914.

President. H. D. Bush; Secretary-Treasurer, Charles J. Tilden, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

President, Robert Hoffmann; Secretary-Treasurer, George H. Tinker, Hickox Building, Cleveland, Ohio.

District of Columbia Association, Organized 1916.

President, A. P. Davis; Secretary-Treasurer, John C. Hoyt, U. S. Geological Survey, Washington, D. C.

Illinois Association, Organized 1916.

President, Onward Bates; Secretary-Treasurer, E. N. Layfield, 4251 Vincennes Avenue, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

President, W. B. Gregory; Secretary, Charles W. Okey, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Northwestern Association, Organized 1914.

President, W. L. Darling; Secretary, Ralph D. Thomas, Minneapolis, Minn.

Philadelphia Association, Organized 1913.

President, Edward B. Temple; Secretary, W. L. Stevenson, 412 City Hall, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers'

Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

Portland, Ore., Association, Organized 1913.

President, J. P. Newell; Secretary, J. A. Currey, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1914.

President, J. A. Ockerson; Secretary-Treasurer, Gurdon G. Black, 34 East Grand Avenue, St. Louis, Mo.

The meetings of the Association are held at the Engineers' Club Auditorium. The Annual Meeting is held on the fourth Monday in November. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

San Diego Association, Organized 1915.

President, N. B. Kellogg; Secretary-Treasurer, J. R. Comly, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

President, A. O. Powell; Secretary-Treasurer, Carl H. Reeves, 4722 Latona Avenue, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Northold Inn, 212 University Street.

Southern California Association, Organized 1914.

President William Mulholland; Secretary, W. K. Barnard, 1105 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

President, Ulysses B. Hough; Secretary, A. D. Butler, Spokane, Wash.

Texas Association, Organized 1913.

President, John B. Hawley; Secretary, J. F. Witt, Dallas, Tex.

Utah Association, Organized 1916.

President, E. C. La Rue; Secretary-Treasurer, H. S. Kleinschmidt, 306 Dooley Building, Salt Lake City, Utah.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Materials for Road Construction

September 23d, 1916.—The meeting was called to order at the House of the Society. Present, George W. Tillson (Chairman *pro tem.*), H. K. Bishop, A. W. Dean, Nelson P. Lewis, Charles J. Tilden, and A. H. Blanchard (Secretary).

The minutes of the meeting of July 8th, 1916, were read and approved.

The following sections of the 1917 Report were presented, discussed, and tentatively adopted: Gravel Roads, by Mr. Bishop; Broken Stone Roads, Broken Stone Roads with Bituminous Surfaces, and Bituminous Macadam Pavements, by Mr. Dean; Asphalt Block Pavements, Sheet-Asphalt Pavements, and Joints and Expansion-Contraction Joints under General Conclusions, by Mr. Blanchard; and Cement-Concrete Pavements, by Mr. Tilden.

On motion, the Committee adjourned to meet on October 21st, 1916.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur= und Architekten=Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From September 6th to October 3d, 1916)

DONATIONS*

EXAMPLES IN ALTERNATING-CURRENTS, VOL. I.

By F. E. Austin. Second Edition, with Additions. Leather, 7 x 5 in., illus. 223 pp. Hanover, N. H., F. E. Austin, 1916. $2.40. (Donated by the Author.)

The popular demand for this work, as stated in the preface, has made the second edition necessary. The book has been designed to assist the college student, to act as a guide in the solution of engineering problems, and also, it is said, will be of value to teachers and to those who are studying the subject independently. One of its important features, it is stated, consists of various tables containing values of variable quantities met with in engineering practice, so arranged as to include a wide range of values and to render evaluation convenient and rapid. There is an index of seven pages.

THE PLANNING OF THE MODERN CITY:

A Review of the Principles Governing City Planning. By Nelson P. Lewis, M. Am. Soc. C. E. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 15 + 423 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $3.50. (Donated by the Author.)

This book is devoted entirely to the engineering aspects of city planning, or to city planning as an engineering problem or group of problems, and the subjects discussed herein are those with which the engineer who is responsible for the working out of a general plan for a city or for successive additions to an existing city, should be familiar. As there is no undertaking which demands more careful study of what has happened elsewhere, what is likely to happen in a particular place, and the development of tendencies which are sure to result in changes in methods of living and of conducting business, as city planning, the author hopes that municipal engineers will find this book of value in bringing to them a keener realization of their part in, and responsibility for, that work. The subject-matter is illustrated fully with photographs and diagrams and plans, showing what has recently been done and what is being planned and executed at the present time, in the way of city planning, in the United States, Europe, and South America. The Contents are: Introductory; The City Planning Movement; The Correction of Mistakes; Elements of a City Plan; The Transportation System; The Street System; Parks and Recreation Facilities; Public Buildings and Civic Centers; The Economic Value of a City Plan; The Industrial Town or District; Street Traffic; Street Details—Utility and Adornment; The Railroad in Its Relation to the Street System; Restrictions; The Environs of the City; Garden Cities; City Planning Legislation; Progress and Methods; Financing a City Plan; Municipal Land Policies; The Opportunities and Responsibilities of the Municipal Engineer; Sources of Information; Index.

STRESSES IN STRUCTURES.

By A. H. Heller. Revised by Clyde T. Morris, M. Am. Soc. C. E. Third Edition. Cloth, $9\frac{1}{4}$ x $6\frac{1}{4}$ in., illus., 18 + 374 pp. New York, John Wiley & Sons, Inc.; London, Chapman & Hall, Limited, 1916. $2.75.

The first edition of this book was published in 1905, and in the preface to that edition, it is stated that the author's aim was to supply, in one volume, a textbook covering stresses in all forms of simple trusses, which would also serve as a reference book for the practicing engineer. In the preface to the third edition, it is said that the explanations contained in the text have been expanded, numerous examples have been given to illustrate the methods used, and many of the figures have been re-drawn and new ones added. Chapters V and VI have been combined to be Chapter V which includes an explanation of Bow's notation and a new article on derricks. Chapter IX has been expanded into two chapters, X on Roof Trusses and XI on Bridge Trusses. In Chapter XII, solutions have been added for the deck Pratt, subdivided Warren,

* Unless otherwise specified, books in this list have been donated by the publishers.

Whipple, and Pettit trusses, and skew bridges. In Chapter XIII, a complete solution of the stresses in a Pratt truss railroad bridge from wheel loads is added and a moment table is given for Cooper's loading, and in Chapter XIV a more complete explanation is given of the solution of the stresses in bridges with curved track. At the end of each chapter are questions and problems referring to the subject discussed in that chapter. The Contents are: Stresses and Deformations Within the Elastic Limits; Stresses and Deformations Beyond the Elastic Limit; The Laws of Equilibrium and Their Application; Application of the Laws of Equilibrium to the Structure as a Whole: Reactions; Application of the Laws of Equilibrium to a Part of a Structure: Stresses; Stresses in Beams and Girders; Deflections of Beams and Girders; Special Cases of Beams and Girders Loaded and Supported in Different Ways; Stresses in Blocks and Columns; Roof Trusses; Bridge Trusses; Stresses in Simple Bridge Trusses for Uniform Loads; Stresses in Railway Bridges from Wheel Loads; Stresses in Bridges from Horizontal Forces; Index.

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(From September 6th to October 3d, 1916)

Donations (including 1 duplicate) 166

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(From September 8th to October 5th, 1916)

ADDITIONS

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BROWER, IRVING CLINTON. Commr. of Public Works, City Hall, Evanston, Ill.	Assoc. M. M.	Nov. 30, 1909 Sept. 12, 1916
BROWN, WILLIAM EDWIN. Res. Engr., East River Tunnels, Public Service Comm., First Dist., 400 East 21st St., Brooklyn, N. Y.		May 31, 1916
BURKE, RALPH HANEY. Chf. Engr., Illinois Waterway Comm., 1104 Peoples Life Bldg., Chicago, Ill.	Jun. Assoc. M. M.	Dec. 4, 1906 Oct. 4, 1910 Sept. 12, 1916
CARSON, JOHN. Chf. Engr., Duluth Street Ry., 1927 West 3d St., Duluth, Minn.		Sept. 12, 1916
COBB, LOUIS RENO. Reinforced Concrete Designing Engr., Westinghouse, Church, Kerr & Co., 37 Wall St., New York City		Sept. 12, 1916
FORTNEY, CAMDEN PAGE. Asst. Engr., U. S. Engr. Office, Dam 43, Ohio River, Pilcher, Ky.	Jun. Assoc. M. M.	Oct. 2, 1906 Nov. 30, 1909 Sept. 12, 1916
HILPERT, MEIER GEORGE. P. O. Box 754, Harrisburg, Pa.		Sept. 12, 1916
JOHNSON, CHARLES. 7925 Sycamore St., New Orleans, La.	Assoc. M. M.	Feb. 28, 1911 Mar. 14, 1916
McALPINE, WILLIAM HORATIO. Asst. Engr., U. S. Engr. Dept., P. O. Box 72, Louisville, Ky.		Sept. 12, 1916
MASSEY, GEORGE BRAGG. Cons. Engr. (Geo. B. Massey Co.), Peoples Gas Bldg., Chicago, Ill.		Sept. 12, 1916
NOLEN, WILLIAM ISAAC. Asst. Chf. Engr., Tennessee Copper Co., Copperhill, Tenn.	Assoc. M. M.	May 3, 1910 Sept. 12, 1916
PAGON, WILLIAM WATTERS. Cons. Engr. (J. E. Greiner & Co.), 1319 Fidelity Bldg. (Res., 39th and Oak Sts.), Baltimore, Md.	Jun. Assoc. M. M.	Sept. 3, 1907 Dec. 3, 1912 Sept. 12, 1916
REITZE, CHESTER NELSON. Cons. Engr. (Reitze, Storey & Duffy, Inc.), 803 Northern Bank Bldg., Seattle, Wash.		Sept. 12, 1916
ROCKWELL, WILLIAM LINCOLN. With Irrig. Investigations, U. S. Dept. of Agriculture, 337 Federal Bldg., San Antonio, Tex.		Sept. 12, 1916
RODRIGUEZ, ARTURO. Cons. and Contr. Engr., 308 West Seneca St., Ithaca, N. Y.		Sept. 12, 1916
SCHURIG, ERNEST GEORGE. Supt. of Constr., U. S. Treasury Dept., Newark, Ohio		Sept. 12, 1916
SEASTONE, CHARLES VICTOR. Cons. Engr., 530 State St., Madison, Wis.	Assoc. M. M.	Dec. 5, 1906 Sept. 12, 1916

MEMBERS (*Continued*)

		Date of Membership.
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SKINNER, FENWICK FENTON. (F. F. Skinner & Co.), 21 Park Row, Room 1705, New York City		Sept. 12, 1916
THORLEY, IRA OTIS. 310 Congress Bldg., Detroit, Mich	Assoc. M. M.	Oct. 29, 1912 Sept. 12, 1916
TURNER, HOWARD MOORE. Hydr. Engr., Turners Falls Power & Elec. Co., Turners Falls, Mass	Assoc. M. M.	April 1, 1914 Sept. 12, 1916
VAN SUETENDAEL, ACHILLE OCTAVE. Chf. Structural Engr., Dept. of State Architecture, New York State, 101 Lancaster St., Albany, N. Y	Jun. Assoc. M. M.	Jan. 3, 1905 June 3, 1908 Sept. 12, 1916
WARD, THOMAS ROBERT JOHN. Chf. Engr. and Secy. to the Govt. of the Punjab, Irrig. Branch, Public Works Dept., Simla, India		June 23, 1916
WATSON, ROBERT MALCOLM. Gen. Municipal Engr. (Wise & Watson); Borough Engr., Rutherford and North Arlington, 46 Ridge Rd., Rutherford, N. J		April 18, 1916
WOOLFOLK, WILLIAM GORDON. Mgr., Chicago Office, Sanderson & Porter, 72 West Adams St., Chicago, Ill		Sept. 12, 1916

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BABBITT, HAROLD EATON. Instr., Municipal and San. Eng., Univ. of Illinois, 907 West Oregon St., Urbana, Ill	Jun. Assoc. M.	April 2, 1912 Sept. 12, 1916
BARNES, JOHN WADDINGTON HARRY. Engr., Madera Canal & Irrig. Co., Box 111, Madera, Cal		Sept. 12, 1916
BATTIE, HERBERT SCANDLIN. Care, S. Risler, Am. Bridge Co., Gary, Ind	Jun. Assoc. M.	Dec. 1, 1908 Sept. 12, 1916
BERGAN, THOMAS BERNARD. City Engr., Auburn, N. Y		April 18, 1916
BOVYER, WILLIAM BLAIR. Asst. City Engr., 760 Eighth Ave., San Francisco, Cal	Jun. Assoc. M.	Oct. 1, 1913 Sept. 12, 1916
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BRYSON, CARLYLE HUGO. City Engr., Lima, Ohio	Jun. Assoc. M.	Mar. 2, 1915 Sept. 12, 1916
CADWALLADER, WALLACE LAIRD. With R. D. Coombs & Co., 30 Church St., Room 236 E, New York City	Jun. Assoc. M.	Sept. 6, 1910 May 31, 1916
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CURRIE, THOMAS AUSTIN, JR. With Stone & Webster Eng. Corporation, 69 Gainsborough St., Suite 6, Boston, Mass.		Sept. 12, 1916
DADING, CHARLES HENRY. Structural Engr. and Estimator, James H. Wells, 69 West Manheim St., Germantown, Philadelphia, Pa		Sept. 12, 1916
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DURANT, WILLIAM BULLARD. 9 Lowell St., Cambridge, Mass	Jun. Assoc. M.	Jan. 6, 1915 Sept. 12, 1916
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FIXEN, VICTOR LEROY. Testing Engr., C. A. P. Turner, 2035 Lincoln Ave., St. Paul, Minn		Sept. 12, 1916
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GILMAN, EDGAR DOW. Instr., Experimental Hydr. Eng., Univ. of Minnesota, Minneapolis, Minn	Jun. Assoc. M.	April 1, 1914 Sept. 12, 1916
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GREELY, FRANK STICKNEY. U. S. Engr. Office, Burke Bldg., Seattle, Wash		April 18, 1916
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GUERDRUM, GEORGE HAGBART. Care, U. S. Geological Survey, Wanakena, N. Y		May 31, 1916
HAMILTON, PETER DAVIDSON GUNN. With Stone & Webster Eng. Corporation, 148 Dedham Ave., Needham, Mass	Jun. Assoc. M.	Feb. 4, 1913 Sept. 12, 1916
HANINK, HERMAN HENRY. Structural Engr., State of Illinois; Chf. Engr., Green & Sons Co., Palos Park, Ill		Sept. 12, 1916
HART, LAURANCE HASTINGS. Asst. Engr., Lupfer & Remick, 594 Ellicott Sq., Buffalo, N. Y	Jun. Assoc. M.	Oct. 3, 1911 June 23, 1916

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HOWARD, JOHN SPENCE. Chf. Engr., The Thomas Hampton Co.; Cons. Engr., 12 East Lexington St., Baltimore, Md		Sept. 12, 1916
HYMAN, ARTHUR DAVID. Waterproofing Engr. and Contr. (The Waterproofing & Constr. Co.), 50 East 42d St., New York City		Sept. 12, 1916
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LAWTON, FREDERICK TYLER. Asst. Engr., Dept. of State Engr. and Surv., 1073 Seventy-fourth St., Brooklyn, N. Y		June 23, 1916
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McCLAIN, CARL ARTHUR. 519 East State St., Ithaca, N. Y.		Sept. 12, 1916
MAERKER, ERWIN. Care, Fargo Eng. Co., 226 West Main St., Jackson, Mich		Sept. 12, 1916
MARKS, EDWIN HALL. Capt., Corps of Engrs., U. S. A., West Point, N. Y	Jun. Assoc. M.	Sept. 3, 1913 Sept. 12, 1916
MICHAEL, WILLIAM WHIPPLE. 44 Maiden Lane, Kingston, N. Y		Sept. 12, 1916
MORRISON, WILLIAM GROVER. Contr. (Morrison Constr. Co.), 311 Hubbell Bldg., Des Moines, Iowa	Jun. Assoc. M.	April 2, 1912 Sept. 12, 1916
NORTON, ALBERT COLWELL. Pres., The Norton Eng. & Contr. Co., 2046 Vine St., Denver, Colo		Sept. 12, 1916
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SAYER, FRED DENNISTON. Borough Engr. and Supt., Municipal Water Dept., Brookville, Pa		Sept. 12, 1916
SCHEDLER, CARL WILLIAM, JR. Supt., Great Western Electro-Chemical Co., Box 582, Pittsburg, Cal	Jun. Assoc. M.	May 2, 1911 Sept. 12, 1916
SCHMIDT, JOHN GEORGE. Chf. Engr., Dept. of Public Service, City Hall, Norwood, Ohio		Sept. 12, 1916

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SELTZER, HYMEN AARON. Eng. Dept., Christopher & Simpson Iron Works Co., 8th and Park Ave. (Res., 5133 Cates Ave.), St. Louis, Mo	Jun. Assoc. M.	May 2, 1911 Sept. 12, 1916
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STRONG, SIDNEY DAVIS. Junior Engr., U. S. Engr. Office, Sault Ste. Marie, Mich	Jun. Assoc. M.	Nov. 5, 1907 Mar. 14, 1916
THOMA, JOSEPH C. U. S. Surv. of Gen. Land Office, 267 East 4th South St., Salt Lake City, Utah		Sept. 12, 1916
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WILLIAMS, FREDERICK. U. S. Surv. and Draftsman, U. S. Engr. Office, New London, Conn.	Jun. Assoc. M.	Oct. 29, 1912 Sept. 12, 1916
WILSON, WILLIAM WEST. Care, D. W. Lum, Special Engr., So. Ry., Washington, D. C	Jun. Assoc. M.	Dec. 4, 1906 April 18, 1916
WOLFF, ALFRED DANIEL, JR. Res. Engr., N. Y. C. R. R., 24 Forbus St., Poughkeepsie, N. Y	Jun. Assoc. M.	Feb. 28, 1911 Sept. 12, 1916
WRIGHT, RENE BARBER. Asst. Engr., Bureau of Highways and Bridges, 620 Miller Ave., Portland, Ore	Jun. Assoc. M.	Aug. 31, 1909 April 18, 1916

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KNISKERN, PHILIP WHEELER. (Knap & Kniskern Co.), 19 South La Salle St., Chicago, Ill	Sept. 12, 1916
KORA, DAHYABHAI BALABHAI. Asst. Engr., Gondal State, Gondal (Kathiawer), Bombay Presidency, India	May 31, 1916
LEHRBACH, HENRY GARDNER. Asst. Engr., Inspection Dept., Dunn Wire Cut Lug Brick Co., Conneaut, Ohio	Mar. 14, 1916
MARRIAN, RALPH RICHARDSON. Co. L, 7th New York Infantry, McAllen, Tex.	April 18, 1916
MATTHEW, RAYMOND. Prof. of Irrig. Eng., New Mexico Coll. of Agriculture and Mechanic Arts, P. O. Box 31, State College, N. Mex	May 31, 1916
SPOONER, RAY NEWHALL. Superintending Engr., Allen N. Spooner & Son, Inc.; Res., 259 Parkside Ave., Brooklyn, N. Y	Sept. 12, 1916
TILTON, GEORGE ALBERT, JR. Eng. Draftsman, City Engr.'s Office, 1162 North Alexandria Ave., Los Angeles, Cal.	Sept. 12, 1916
WEED, LLOYD WOOLSEY. Designing Engr., Turner Constr. Co., 307 West 70th St., New York City	Sept. 12, 1916
WOOLWORTH, WENDELL HOWARD. Co. D, 7th New York Infantry, McAllen, Tex	Sept. 12, 1916

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BUEHLER, WALTER. Cons. Engr., Wood Preservation, 5756 Kenmore Ave., Chicago, Ill.

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CLARK, ERNEST ALDEN. Chf. Engr., Eng. Constr. Co., 501 Marshall St., Room 23, Milwaukee, Wis.

CODE, WILLIAM HENRY. Cons. Engr. (Quinton, Code & Hill), 1112 Hollingsworth Bldg. (Res., 7231 Hillside Ave.), Los Angeles, Cal.

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DAVIS, CHARLES STRATTON. Senior Structural Engr., Div. of Valuation, Interstate Commerce Comm., 802 Penobscot Bldg., Detroit, Mich.

DOOLITTLE, HAROLD JAMES. Asst. Engr., State Highway Dept., 437 West 15th Ave., Spokane, Wash.

DREW, CHARLES DAVIS. Res. Engr., East River Tunnels, Public Service Comm., 159 Remsen St., Brooklyn, N. Y.

EARLY, PERCY WALKER. Asst. Gen. Mgr., Robert Grace Contr. Co., 442 South Court St., Crown Point, Ind.

GEHLER, GUSTAV WILLY. Prof., Technische Hochschule, Dresden, Germany.

HARRIS, VAN ALEN. 43 West Walnut Lane, Germantown, Philadelphia, Pa.

HENDERSON, HENRI HERBERT. 311 East Main St., Stockton, Cal.

HORROCKS, JOHN IRVIN. (B. H. M. Lumber Co.), Darrington, Wash.

HORTENSTINE, HENRY ROBERTS. Sales Mgr. and Chf. Engr., Independent Bridge Co. (Res., 52 South Harrison Ave., Bellevue), Pittsburgh, Pa.

HOTCHKISS, LOUIS JENISON. 1215 Manadnock Bldg. (Res., 4617 Beacon St.), Chicago, Ill.

JOHANNESSON, SIGVALD. Asst. Engr., I. R. T. Co., Hotel Van Rensselaer, 17 East 11th St., New York City.

MEMBERS (*Continued*)

KERSTING, FELIX JOHN. With Kansas City Bridge Co. (Res., 2938 East 28th St.), Kansas City, Mo.

LEEDS, CHARLES TILESTON. Capt., Corps of Engrs. U. S. A. (*Retired*); Cons. Engr., 1105 Central Bldg., Los Angeles, Cal.

MACREDIE, JOHN ROBERT CLARKE. Empress, Alberta, Canada.

MCGREW, ANSON BURLINGAME. U. S. Asst. Engr., U. S. Engr. Office, Lock No. 4, Pa.

MATHER, THOMAS HOGGAN. Mfrs.' Agt., 419 First National Bank Bldg. (Res., 211 Comstock Ave.), Syracuse, N. Y.

MATHEWSON, THOMAS KNIGHT. Guasave, Sinaloa, *via* Bamoa, Mexico.

MORRIS, MARSHALL, JR. Care, Walsh & Burney, Box 1140, Austin, Tex.

MORRISON, HARRY JOHNSON. Box 197, Beckley, W. Va.

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DEATHS

BLOSS, RICHARD PARKHURST. Elected Member, January 6th, 1904; died May 22d, 1916.

BOYNTON, ROBERT HAMMOND. Elected Junior, May 6th, 1914; Associate Member, April 18th, 1916; died September 18th, 1916.

CALDWELL, CHARLES ADOLPHUS. Elected Member, September 5th, 1911; died August 31st, 1916.

STANTON, FRANK MCMILLAN. Elected Member, February 1st, 1899; died September 11th, 1916.

Total Membership of the Society, October 5th, 1916, 8 116.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(September 2d to October 2d, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age*, New York City, 10c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.
(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.

(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron*, Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 20c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Iron Tradesman*, Atlanta, Ga., 10c.
(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal*, Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas*, San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung*, Leipzig, Germany.
(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal*, Engrs.' Club of St. Louis, St. Lous, Mo., 35c.
(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Standard Plans for I-Beam and Concrete Bridges.* (13) Sept. 7.
Foundation Work on the Metropolis Bridge.* (15) Sept. 8.
Reinforced-Concrete Arch has Masonry Facing.* (14) Sept. 9.
Erection of Quebec Bridge Suspended Span.* A. J. Meyers. (13) Sept. 14.
Wind Damages Highway Bridge.* (14) Sept. 16.
Little Plant Required to Complete 4 000-Ft. Concrete Railroad Bridge.* (14) Sept. 16.
The Full Evidence on the Fall of the Quebec Bridge Span.* (13) Sept. 21.
Shallow Railway Floor on Canal Bascule Bridge.* Arthur G. Hayden. (13) Sept. 21.

* Illustrated.

Bridges—(Continued).

The Cause of the Quebec Bridge Disaster.* (15) Sept. 22; (18) Sept. 23; (96) Sept. 21; (13) Sept. 14.
Revolutionary Methods Used to Float and Hoist Center Span of Quebec Bridge.* (14) Sept. 23.
Breakage of Casting of Rocker-Joint Bearing Responsible for Quebec Bridge Disaster.* (14) Sept. 23; (20) Sept. 21.
Hopple Street Viaduct, Cincinnati, is Built with Cantilever Beams of Arch Form.* Edgar K. Ruth. (14) Sept. 23.
Reinforced-Concrete Pipe Used for Railway Culverts.* (13) Sept. 28.
Test of New Type Reinforced-Concrete Bridge.* (13) Sept. 28.
Central Bridge at Lawrence is Built from Four Separate Mixing Plants.* E. K. Cortright. (14) Sept. 30.
Les Ponts Militaires pour l'Etablissement de Passages Provisoires Ponts Métallique Démontables.* A. Bidault des Chaumes. (33) Aug. 19.
Nouveau Pont en Béton Armé sur le Mississippi à Minneapolis (Minnesota, Etats-Unis).* (33) Sept. 9.

Electrical.

Approximate Solution of Short-Circuit Problems.* E. G. Merrick. (73) Aug. 25.
An Approximate Method of Calculating Short-Circuit Current in an Alternating-Current System.* H. R. Wilson. (73) Aug. 25.
Prevention of Condenser Corrosion (Electrolytic method). J. F. Peter. (Paper read before the Inst. of Marine Engrs.) (26) Aug. 25.
Paisley Automatic Telephone Exchange.* J. Hedley. (73) Aug. 25.
The Determination of the Constant of a Solenoid.* S. R. Williams. (3) Sept.
Originality in Street Lighting Standards.* Albert Marple. (60) Sept.
Inductive Interference as a Practical Problem.* A. H. Griswold and R. W. Mastick. (42) Sept.
The Characteristics of Tungsten Filaments as Functions of Temperature. Irving Langmuir. (73) Sept. 1.
The Active Materials and Electrolyte of the Alkaline Storage Battery. L. C. Turnock. (105) Sept. 1.
The Sperry Searchlight. (11) Sept. 1; (26) Sept. 8.
Switchboards for Polyphase Testing.* A. T. Bullen. (26) Sept. 1.
Downtown Lighting System for San Francisco.* Walter D'Arcy Ryan. (27) Sept. 2.
Impedances of Iron and Steel Wire. Clem A. Copeland. (111) Sept. 2.
Lighting That Combines Art and Science.* Louis Bell. (27) Sept. 2.
Street Lighting System of Sheboygan, Wis.* Carroll H. Shaw. (27) Sept. 2.
Electrical Machine Bearings.* Gordon Fox. (64) Sept. 5.
Twin-City Power Plants.* Thomas Wilson. (64) Sept. 5.
The Influence of Pressure on the Electrical Ignition of Methane.* W. M. Thornton. (Paper read before Section G of the British Assoc.) (73) Sept. 8.
1 500 K.w. Geared Turbo-Generator at the Westinghouse Works, Trafford Park, Manchester.* (11) Serial beginning Sept. 8.
The Calculation of the Capacity of Radio-Telegraph Antennæ, Including the Effects of Masts and Buildings.* G. W. O. Howe. (Abstract of paper read before Section G of the British Assoc.) (73) Sept. 8.
Electric Signalling With Bare Wires. Sydney F. Walker. (22) Sept. 8.
Eliminating Transmission Line Telephone Troubles.* E. P. Peck. (27) Sept. 9.
Operation of a Small Diesel Engine Plant.* (27) Sept. 9.
The Fuller Electrical Manufacturing Works. Chadwell Heath.* (26) Sept. 15.
Operation of a Non-Synchronous Rotating Gap.* A. S. Blatterman. (27) Sept. 16.
Making Cable Joints with Formed Insulation.* (27) Sept. 16.
Service Connections from Underground Mains.* E. B. Meyer. (27) Sept. 16.
Electrification of a Modern Cement Company.* D. C. Findlay. (111) Serial beginning Sept. 16.
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Les Sous-Stations de Transformation en Plein Air.* J. Vichniak. (33) Aug. 19.
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Die Berücksichtigung des Wicklungssinnes in der theoretischen Elektrotechnik.* Otto Block. (107) Sept. 9.

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Marine.

The Sperry Active Gyroscope for Stabilising Ships.* (12) Aug. 25.
The Ljungström Turbine and Its Application to Marine Propulsion. Ronald S. Portham. (47) Sept. 1.
Machine Shops on the United States Repair Ship *Prometheus*.* Frank A. Stanley. (72) Sept. 7.
Light Cruisers in the War. (12) Sept. 8.
Craig Marine Diesel.* (64) Sept. 26.
Floating Foundry and Forge Shop.* (72) Sept. 28.
Le *Ceara*, Navire-Dépot pour les Sous-Marins de la Marine brésilienne.* Ch. Dantin. (33) Aug. 19.

Mechanical.

Power with By-Product Recovery.* T. Roland Wollaston. (12) Aug. 25.
Boilers Heated by Coke-Oven Gas.* (22) Serial beginning Aug. 25.
On the Determination of the Leakages in Gas-Pipes.* Michelangelo Boehm. (66) Aug. 29.
Electric Welding in Boiler Shop Repairs. P. E. Gallagher. (Paper read before Master Boiler Makers' Assoc.) (62) Sept.
Production of Dies and Marking Devices.* Charles C. Lynde. (62) Sept.
Straight Line Forge Shop Plant Lay-out.* C. S. Kinnison. (62) Sept.
Operating Costs in Combined Power and Heating Plants.* Charles L. Hubbard. (9) Sept.
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PAPERS AND DISCUSSIONS

OCTOBER, 1916

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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VOL. XLII. OCTOBER, 1916. No. 8.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

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THE YALE BOWL

By Charles A. Ferry, M. Am. Soc. C. E.

To be Presented November 15th, 1916.

Synopsis.

This paper is descriptive of the new amphitheater constructed for the Athletic Department of Yale University. It is the largest structure of the kind in the world, and provides seating accommodation for nearly 61 000 spectators, a press-stand for about 250 reporters, and a photographers' stand for about 50 operators. It is in the form of a four-center oval, 300 by 500 ft. from face to face of the inner retaining walls, and about 750 by 930 ft. over all, covering an area of about 12½ acres.

The points to be observed in planning the structure were: large seating capacity; ample entrances, in order to avoid congestion at any point; strength and durability, with low cost both for construction and maintenance; and safety, especially for spectators. To meet these conditions, an excavation about 27½ ft. deep was made on the area required for a playing field, and the material thus obtained was used for building a surrounding embankment to a height of about 26 ft. above the general surface of the ground, its inner slope being continuous with that of the excavation.

The inner face of the slope, in excavation, was covered with reinforced concrete, built in the form of steps, on which were fastened

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

benches for the spectators. A temporary wood facing, with benches, was built on the inner slope of the embankment, for use until the embankment had become consolidated. The outer slope was seeded with grass. Thirty reinforced concrete tunnels give access, through the embankment, to the spectators' seats; and two tunnels for the accommodation of the players, run directly to the field. The drainage from the playing field and the outer slopes of the embankment is taken by a sewer discharging into a river which runs near the Bowl.

The material was placed in the embankment in 6-in. layers, each thoroughly watered, and then rolled with two rollers, one grooved and the other smooth, one following in the track of the other. Drag-line scrapers, operated from 85-ft. towers running on a four-rail track laid outside the structure, and steam shovels, operating within the Bowl, were used, principally, for building the embankment. The shovels filled bottom-dump wagons which, with the teams of horses, were drawn up the slope by hoisting engines on the top of the embankment. Bottom, side-dump cars, and chutes were used for conveying the concrete from the mixers.

One of the special features of the construction is a cantilever retaining wall, 45½ ft. high, which forms one of the walls of the proposed gate-house.

History.

Football, the most popular of college athletic sports, though one of the oldest, is, under its new rules, one of the most modern of field sports. The first intercollegiate football match in the United States, between Yale and Harvard, was played in 1876, and Mr. Walter Camp, the so-called father of American football, is still one of the most valued advisors of Yale teams.

It was not until 1896, however, that the attendance at Yale games called for special accommodations for spectators at the intercollegiate matches. In that year, the Yale Athletic Association, to provide for any probable future demand for seats, built a stand to accommodate about 18 000 persons. Contrary to expectations, however, this stand soon proved inadequate to meet the demand for seats from those who desired to witness the "big" games, and additions to the stands were

made from time to time until they finally contained 33 090 sittings and the practical limit of size for a stand in that location was reached. These, so far as the writer knows, were the largest wooden stands ever erected.

In 1904 Harvard erected its steel and reinforced concrete stadium, to accommodate about 23 000 spectators.

As the wooden stands at Yale were not painted, exposure to the weather caused rapid deterioration, and the annual expense for repairs amounted to from $10 000 to $12 000. In addition to this tax, the danger of the destruction of the stands, by fire or otherwise, immediately preceding the date set for a game, thereby necessitating its cancellation, and the thought of the much greater catastrophe of a fire occurring in them during the progress of a game, thereby creating a panic in the great crowd of spectators, caused much anxiety on the part of the management, and, in 1910, resulted in a movement to secure a permanent, more commodious, and fire-proof structure.

The Corporation of the University appointed a committee of seven graduates to consider the whole question of athletic development at the University and the provision of suitable accommodations for spectators at intercollegiate games. This committee recommended an increase in the facilities for out-door athletics, and the erection of a stadium for football; and, on its further recommendation, a committee of twenty-one was appointed to carry the latter into effect.

This committee was organized under the name of "The Yale Committee of Twenty-one, Incorporated", and began to carry its instructions into effect by the purchase of about 87 acres of land near the old athletic field, which, with the latter, gave a total area of about 110 acres available for development, divided into five separate fields by intersecting streets.

Three plans of widely varying type were suggested for the proposed stadium: First, a steel structure composed of separate units mounted on wheels and designed so that these units could be moved in such manner as to provide a stand for either football or baseball as necessity might require; second, a reinforced concrete structure based on the model of the Roman Colosseum, to seat 50 000 persons and designed for football only; and third, the plan suggested by the writer, for a stand constructed of earth faced with concrete, somewhat similar to reservoir construction, from which the idea was derived.

The first plan offered difficulties in the way of providing for suitably rigid foundations, on which the sections of the stand could be moved, without interfering with the playing fields; the second was prohibitive on account of its cost, which was estimated to be about \$750 000. The third plan, offering as it did a stable, permanent, and fire-proof structure at a minimum of cost, both for construction and maintenance, was, as subsequently modified, adopted.

The plan as first presented was markedly different in shape from the Bowl as constructed, although the method of construction was the same. As first planned, it provided for football and baseball fields, with a quarter-mile running track, a 220-yd. straight-away track, and spaces for pole vaulting and jumping events, all surrounded by a single stand, an irregular heptagon in shape and of sufficient size to seat 50 000 persons. This stand was estimated to cost about \$170 000.

Objection being made to having any part of the baseball field used for football and on account of the possible interference, in practice, by teams in different departments of athletics, the writer was requested to change the plans to provide for football only, and a structure, substantially on the lines of the present Bowl, was designed. This, for a seating capacity of 50 000, was estimated to cost about \$235 000. In this plan the outer retaining wall and the tunnels, except the main tunnels to the field, were omitted, the entrances for the spectators being by steps leading over the top of the embankment. With the change in plans to provide for 60 000 spectators, the embankment became so high that tunnels for entrances became desirable, and this necessitated the erection of the outer retaining wall.

During the development of the plans, two questions were prominently raised concerning the probable stability of a concrete structure built on an earth slope varying from 1 on $2\frac{1}{2}$ to 1 on 4: First, whether expansion and contraction, due to temperature changes, and the heaving effects of frost in the underlying sand would not gradually move the concrete down the slope and, eventually, pile it in a disordered heap at the bottom; and second, whether material in the embankment could be compacted so solidly that subsequent settlement would not crack the concrete injuriously.

To answer the first of these questions so far as possible a few simple experiments were made regarding frost action. A sample of the sand was taken from the field within a few hours after a very heavy rain,

and it was found that only about 23% of the volume of the voids was filled with water, the total volume of the voids being about 37% of the volume of the sand when compacted. A bottle, about 10 in. in length and 1 in. in diameter, with a sharply contracted neck, was then filled with sand thoroughly compacted, and with sufficient water added to fill 23% of the voids. The mixture was then frozen, but no indication of any expansion of the mass was noticed. A similar experiment with 50% of the voids filled with water produced a like result. The experiment was then repeated with 75% of the voids filled, and the bottom of the bottle was cracked off.

To ascertain the extent to which water would be retained in the sand by capillary action, the bottle was filled with sand saturated with water. A piece of linen was then tied over the mouth of the bottle which was then reversed and the water allowed to drip. In 2 min. about 16% of the water had run out. The bottle was then set, mouth down, in a bed of sand, the broken off bottom being replaced in order to lessen evaporation from that end. After 24 hours 67% of the water had run out, and 80% at the end of 8 days. It was concluded, therefore, that, as the slope was to be entirely covered with concrete, thereby excluding all water except such as could pass through the expansion joints, the danger of any disintegrating effect resulting from frost in the underlying sand might be neglected.

As the steps were to be built in the form of horizontal arches, it was thought that these would take care of any possible movement due to temperature changes.

To provide for a possible settlement of the embankment, it was suggested that the steps be built in the form of reinforced concrete slabs, somewhat after the plan in the Harvard Stadium, supported on reinforced concrete girders resting on concrete piers built into the earth, the girders being raised a few inches above the face of the slope. Then, in case of any settlement, the girders could be shimmed up on the piers, and the structure restored to its original form. The estimated cost of this plan, however, proved to be so much in excess of that for concreting directly on the earth that it was abandoned, and it was decided to concrete first only the portion of the slope in excavation, and to provide the face of the embankment, temporarily, with a wooden superstructure, until such time as the embankment had ceased to settle.

Description.

The Bowl, as constructed, has a playing field, oval in plan, 300 by 500 ft., varying from a true ellipse by about 6 ft. at the point of greatest divergence, the radius of the sides being 420 ft. and that of the ends 120 ft.

The old wooden stands had been built with straight sides and ends, the corners being filled in with sections at 45° to these lines. The Harvard and Princeton Stadia have straight, parallel sides, joined by a curved section at one end, the other being left open. In such stands a person occupying a seat on a side near one end cannot get a good view of plays on the same side of the field near the opposite end. The oval form was adopted for the Bowl in order that all the spectators might have an unobstructed view of the plays in whatever part of the field they might occur. This form also enables each spectator to obtain a view of the entire audience, a very thrilling spectacle when all the seats are filled and every one is roused to a high pitch of excitement by some brilliant play.

The space between the outer lines of the gridiron and the surrounding wall is of sufficient width to permit of a running track, 20 ft. wide and of a length only 200 ft. short of ¼ mile. As there was not room for a 220-yd. straight-away track—a feature which is considered necessary for an athletic field—without tunneling under the seating section, the track feature has been abandoned for the Bowl. The playing field is laid out so that the 5-yd. lines point toward the sun at 3 P. M. in the middle of November, the time when the principal match games are played, thus making the lighting of the two ends of the field the same.

The earth was scooped out over the area to be occupied by the playing field and piled up in an embankment surrounding it, the inner slope of the latter being continuous with that of the inner face of the excavation. The depth of the excavation was about 27½ ft. below the general surface of the ground, and the top of the embankment about 26 ft. above it, making the total elevation from the surface of the field to the top of the fill 53½ ft.

The inner face of the slope was graded to a smooth surface, with vertical as well as horizontal curves, to serve as a foundation for the sixty concrete steps. The tread of the steps is uniformly 30 in., with the exception of the step at the inner portal of the tunnels, which is 52 in. wide and is used as a cross-aisle. The bottom step is 4 ft. above the

playing field, and the height of the steps increases uniformly by 0.006 ft. from the bottom riser, which is 8 in. high, to the top one, which is 12½ in. high.

The dishing shape, formed by this combination of vertical and horizontal curves, suggested the name "Bowl" which has been given to the structure, and provides advantages to the spectators for viewing proceedings on all parts of the field not possessed by any other large stand. The vertical curve gives a person occupying the top seat the same facility for seeing over the heads of the persons occupying the seats in front of him as that possessed by the spectators in the lower rows, the clearance being practically the same in all the rows of seats from a point about 200 ft. from the inner retaining wall.

The embankment is 15 ft. wide on the top in order to allow room for a promenade, 12½ ft. wide, back of the top row of seats, and then slopes down to a retaining wall, the top of which is 9 ft. above the surface of the ground outside the Bowl. This slope is 1 on 2, except opposite the portals, where it had to be steeper on account of the recessing of the portals into the embankment.

Retaining Walls.

The playing field is surrounded by a retaining wall, 4 ft. high, its top being level with the tread of the bottom step of the seating section. This wall is surmounted by a parapet which, with a 12-in. coping, is 27 in. high. The outer retaining wall is finished with a coping 12 in. thick, the front, top corner of which is rounded to a curve with a 6-in. radius, in order to render the wall more difficult to scale, in case any one desired to take a short cut, financially, into the Bowl to witness a game. The pilasters project 3 in. from the face of the wall. They are carried up 6 in. above its top, and are finished with a cap 30 in. square over the front portion of the wall. For convenience in construction, both retaining walls were made as chords instead of arcs or circles, the angles being at the pilasters, which also serve as expansion joints. The outer portals are recessed 9 ft. into the embankment, and are joined to the main wall by curved wing-walls.

Tunnels.

Thirty tunnels through the embankment are provided as entrances to the amphitheater for spectators. These are all 7 ft. wide and 8 ft.

high. They start from the level of the ground outside the Bowl and terminate at the twenty-fifth row of seats from the bottom, where they are spaced uniformly along the cross-aisle. As the level of the ground opposite the main gate-house is 11 ft. lower than that on the opposite side, these tunnels are all on a slope, those on the westerly side being down toward the field on a maximum grade of 2.37%, and those on the easterly side up on a maximum grade of 4.18 per cent. The end tunnels have grades of 0.24 and 0.26%, respectively, just sufficient to afford good drainage.

In addition to the thirty spectators' tunnels, there are two for the players, which can also be used as exits for the spectators. These run from the level of the ground outside the Bowl directly to the playing field. The one on the easterly side, 15 ft. wide and 10 ft. high, affords facilities for carting in loads of hay or straw, when necessary to protect the field from frost. It has a grade of 6.33 per cent. The other tunnel is 10 ft. wide and 8 ft. high. The difference in elevation between the portals of this tunnel being too great to admit of a straight ramp for its entire length, a double flight of steps, with an intermediate platform 6 ft. wide, was built at the outer end and then a ramp, on a grade of 7.55%, for the remainder of the distance to the field.

The footings of the tunnels were all made monolithic, but the remaining portion was divided into lengths, not exceeding 30 ft., by expansion joints. Each joint was made by inserting in the side-wall forms steel plates bent to form a tongue and groove with flaring sides. On one side of these plates was placed a strip of tarred felt and, as the forms were filled, the plates were drawn up out of them, leaving the felt embedded in the concrete, thereby preventing the bonding of the adjoining sections. This device enabled the contractor to complete a tunnel at one pouring, instead of being obliged to wait two or three days for the concrete in one set of sections to set before pouring the intermediate ones.

The sides and roof of each tunnel are reinforced with steel and, down to a line just below the underside of the roof, are water-proofed with three layers of roofing felt and one layer of Tartex, all cemented together and to the concrete with roofing pitch. On top of this a 1-in. protective coating of cement mortar was laid.

The sides of the tunnels, below the water-proofing, and the backs of the retaining walls, were mopped with hot roofing pitch. Before the

pitch was applied, all rough places on the surface were smoothed over with mortar, and the whole surface was then washed over with a thin grout, to insure the closing of all "pin holes". That this treatment was efficacious in producing a water-tight wall was accidentally demonstrated. Between the end-walls of the large gate-house and two of the adjacent tunnels are spaces about 2¾ ft. wide. The sand in these pockets became covered with concrete and grout, spilled from the chutes during the process of building the walls, which effectually sealed the interstices between the particles of sand, and rendered the pockets practically water-tight. Water from the roof of the tunnels ran into these pockets and, at one time, stood about 6 ft. deep without showing any signs of leakage or even sweating inside the tunnels.

The floor of each tunnel has a granolithic pavement. In the largest tunnel this is 8 in. thick; in all the others it is 6 in.

All the tunnels are well lighted by electricity, there being five 100-watt lamps in each of the spectators' tunnels and six in each of the others. Hemispherical depressions were made in the ceiling, from which lamps project down into Holophane globes suspended from the under side of the roof.

Aisles.

An aisle, 52 in. wide, extends around the entire amphitheater at the inner portals of the tunnels. From this other aisles run down, opposite each portal, to give access to the lower twenty-five rows of seats, and a flight of steps leads from the lower end of each of these aisles to the playing field. Other aisles, one on each side of each spectators' tunnel, afford access to the upper thirty-five rows of seats and to the promenade on the top of the embankment.

Grading.

The surface of the playing field is graded to the form, approximately, of a segment of a football, the ground at the center being 1 ft. higher than that at the foot of the steps. On the narrow strip, 5 ft. wide, next to the retaining wall, the grade is broken so as to drain to the basins under the steps. The field was first graded to a sub-grade 18 in. below the established grade. Black loam, 16 in. deep, was then spread over the field in two layers, each layer being rolled with a 5-ton roller. Boston humus, 1 in. deep, was then spread over the loam and

harrowed into it to a depth of about 3 in., and the entire area was then turfed. A thin layer—about $\frac{1}{8}$ in.—of sifted black loam was then spread over the turf, and grass seed was sowed and raked in. Although the turfing was done during the hot summer, and the foundation of the field was clean sand and gravel, judicious watering caused the grass to begin to grow and, in a few weeks, a firm field with a strong turf was obtained.

No sub-soil drains were laid under the field, as the material is very porous, and the level of the ground-water, as indicated by a well in the vicinity, is about 12 ft. below the surface of the field, thereby insuring good sub-soil drainage.

The outer slope of the embankment was brought to a sub-grade 10 in. below the established grade, and then filled with black loam. Strips of turf, 1 ft. wide, were then laid, 8 ft. apart, parallel to the edge of the promenade. The remainder of the slope was then seeded to grass. The strips of turf were intended to prevent the slope from gullying in case of heavy rains before the grass was sufficiently grown to afford the necessary protection.

Besides the building of the embankment, there was a large amount of grading around the Bowl to make the grades of the surrounding grounds conform to the neighboring streets. In addition, Yale Avenue, a street about 1 500 ft. long and 80 ft. wide, was graded, the maximum cut being about 13 ft. The material from this grading, which was not required in the embankment, was used for filling about 11 acres of marsh, to a depth of about 3 ft., rendering it available as playing fields.

Drainage.

The water falling on the inner slope of the amphitheater is caught in a gutter formed in the top of the retaining wall just in front of the first riser. This gutter is 6 in. wide, and varies in depth from 6 in. at the center of the panels to 9 in. at the aisles. It is covered with a galvanized cast-iron grating. Drain pipes, 6 in. in diameter, run from this gutter, through the wall, and discharge on slightly dishing slabs of concrete built under each of the flights of steps which lead from the aisles to the playing field. In the center of each of these slabs is a small receiving basin, covered with a grating, which connects, by a 6-in. drain, with the drain which encircles the field. These basins also receive the drainage from the field.

The water which falls on the outer slope of the embankment is collected in a gutter formed in the top of the retaining wall near the inner edge. This gutter is 9 in. wide and 6 in. deep, with flaring sides, to lessen the risk of the wall being cracked by ice, and is connected, at the lower end of each section, by a 6-in. drain with the drain which runs around the outside of the Bowl.

The field drain connects with a 24-in. pipe which runs under the main tunnel, and the drain which encircles the structure connects with the same conduit, by a drop-manhole, just outside the front wall of the proposed main gate-house. The main drain discharges into West River, that portion which crosses the marsh being laid on a reinforced concrete slab supported by piles. The capacity of the drains is based on a rainfall of 2 in. per hour.

Water Supply.

To provide facilities for watering the field, the outer slope of the embankment, and the surrounding grounds, there are flush hydrants at frequent intervals around the playing field just inside the inner retaining wall, and outside the Bowl in the portal recesses. These are connected with 4-in. mains laid parallel with the retaining walls both inside and outside the structure, and are supplied with water from the mains of the New Haven Water Company.

Gate-Houses.

Gate-houses, which will contain showers, dressing-rooms, etc., for the teams, will be built at the entrances to each of the large tunnels. Owing to shortage of funds, it was decided to postpone the erection of these buildings until after the completion of the seating portion of the structure. In order to complete the embankment, however, it was necessary to construct the back walls of each of these buildings. The wall of the smaller house is 38 ft. high in its highest part. By using the end and proposed partition walls of the building for buttresses, and by the use of a small quantity of steel reinforcement, a wall was designed which was much lighter than would have been necessary if a gravity section had been built.

The height of the highest portion of the wall for the main gate-house is (including a 3-ft. parapet) 45½ ft. For this wall there was no opportunity to obtain any lateral support from other walls, and a canti-

lever wall was constructed, this type being adopted in preference to a counterfort wall on account of convenience in placing and consolidating the back-filling, although, probably, the latter would have been somewhat cheaper. This is, so far as known to the writer, the highest wall of the cantilever type ever constructed.

The main reinforcing rods in this wall are $1\frac{1}{4}$ in. square. For the lower quarter of the height the rods are 3 in. apart on centers; for the second quarter, 6 in.; for the third quarter, 12 in.; and for the top quarter, 24 in. As the wall was so high that it was impracticable to make these rods in single lengths and extend them down into the footing, they were made in two pieces with an allowance of fifty diameters for a splice just above the top of the footing. The rods were so large and the spacing so close at the bottom that it was deemed advisable to place them in the splice, side by side, on a line at right angles to the direction of the wall. To avoid the danger of the wall being split by the eccentric strains which might be developed by this arrangement, and to assist the concrete in transferring the strain from one set of rods to the other, three clamps were used on each splice, one each at top, bottom, and middle. Tests at the Mason Laboratory of Yale University showed that, with two clamps, a pull of 10 000 lb. was required before the rods would slip, thereby relieving the concrete of so much of its work.

Tool-Rooms.

Rooms for the storage of hose, tools, etc., required in the care of the field and grounds, were made in the embankment, one on each side of the approach to the main tunnel. These rooms are $24\frac{1}{2}$ by $12\frac{1}{2}$ ft., and of varying height, the concrete seating steps forming the ceiling. The entrance doors to the rooms open on the approach to the tunnel.

Concrete Facing.

The concrete facing on the portion of the amphitheater which is in cut was built in sections three steps wide and of lengths varying from $3\frac{1}{2}$ to $17\frac{1}{2}$ ft., depending on the location. Each block is reinforced with steel in both directions and at top and bottom, sufficient reinforcement being used to permit the blocks to sustain a live load of 50 lb. per sq. ft., whether they are supported at the sides, ends, or middle. The blocks, at the circumferential joints, overlap 3 in. and are separated by a layer of tarred felt. All radial joints are butt-jointed, and were given

a coat of roofing pitch, to prevent the bonding of the blocks, but in the middle joint in each panel there was inserted a layer of Elastite, $\frac{3}{8}$ in. thick, to provide for expansion.

The facing was built in alternate blocks, laid checker-board fashion, 3 days being allowed for the setting of the concrete in one set of blocks before the intermediate ones were laid. The blocks forming the aisles were laid last, as they were the shortest. The slabs were all 7 in. thick in the thinnest part, under the junction of the tread with the riser. In addition to the regular reinforcement, a strip of wire lath, 6 in. wide, was built into each of the aisle steps, $\frac{1}{2}$ in. below the surface, in order to prevent the spalling of the corners of the steps.

To prevent the glare from such a large surface of concrete, if left in its natural color, and to afford variety of coloring, the facing was made a dark slate by the addition of 1 lb. of lampblack to each barrel of cement used in the granolithic surfacing. The inner retaining wall was left in the natural color of the concrete.

Wood Facing.

The wood facing, on the slope of the embankment, consists of 2 by 6-in. sills, laid radially not more than 4 ft. apart. To these were spiked triangular-shaped blocks, 3 in. thick and 18 in. long on the upper edge, for supporting the tread of the steps, which are 18 in. wide, the remainder of the 30-in. space allowed for each row of seats being left uncovered. Although this left the earth slope exposed to the elements, the material in the embankment is so porous and absorbs water so readily that little trouble has been experienced from washing of the embankment.

Seats.

The permanent seats built on the concrete facing consist of 2 by 10-in. planks, with the upper side planed to a curved surface, supported on galvanized-steel standards anchored to the concrete. These standards were made in four different sizes, in order to fit the varying height of the risers and make the height of the seat within the limits of $17\frac{3}{4}$ and $18\frac{1}{4}$ in. The back rest is a $1\frac{1}{4}$ by 5-in. board, with the front face curved and the corners rounded, supported by $2\frac{1}{2}$ by $2\frac{1}{2}$-in. wooden standards bolted to the backs of the steel ones. The wood for the permanent benches is rift-sawed Douglas fir from Oregon. U-shaped Tobin bronze bolts were specified for anchoring the steel standards to

the concrete, but a lower price being offered by the contractor for Sherardized-steel anchor-bolts, the first benches erected were anchored with them, but, as these proved to be not well adapted for the purpose, their use was abandoned, and about two-thirds of the seats are fastened with the bronze bolts as originally planned.

The temporary benches on the wood facing consist of $1\frac{1}{4}$ by 10-in. spruce boards supported by 2 by 12-in. wood standards spiked to the sills. These benches are provided with back rests of the same kind as the permanent seats.

A minimum spacing of $17\frac{3}{4}$ in., with an average of a little more than 18 in. was allowed for each sitting. With this spacing there are 60 617 seats for spectators.

Press-Stand.

A stand for the representatives of the Press was erected on the westerly side of the Bowl, just below the top of the embankment. This is provided with two rows of seats, and shelves for convenience in writing or telegraphing. With a spacing of 21 in., this stand will accommodate 249 persons, sitting. In addition to this, there is provision for three rows of persons, standing, giving accommodations for about 400 additional, or a total of about 650 in the press-stand. Back of the press-stand, and raised a little above it, a stand for photographers will accommodate about 50 operators.

Peculiarity of Seating Arrangements.

The seating arrangements in the Bowl are noticeably different from those in other large stands, such as the Harvard, Princeton, and Syracuse Stadia. The plan of having a low riser for the bottom step and then increasing uniformly to a high one at the top is peculiar to this structure, and has the advantage that, while it gives the spectators occupying the upper rows of seats the same facility for seeing over the heads of those sitting in front of them which the occupants of the lower rows enjoy, it permits of a lower and, consequently, a much cheaper and more stable structure. For example, in the Harvard Stadium the 31 rows of seats occupy a height of about 41 ft.; in the Syracuse Stadium the 18 rows of seats have a height of 27 ft.; in the Princeton Stadium the 48 rows have a height of about 62 ft.; but, in the Bowl, the 60 rows of seats have a height of only $49\frac{1}{2}$ ft. In these other stands, the height of the riser is the height of the seat, the

spectator sitting directly on the concrete step or on a board laid directly on it. Seats thus constructed are not very inviting on a cold day, particularly during a rain storm, when the water is dammed back on the seats by the spectators sitting on them. In the Bowl, the benches are raised a sufficient height above the concrete to permit the water to run freely over the steps without coming into contact with the spectators. The Bowl seats, also, are provided with back rests, but those of these other structures have none.

CONSTRUCTION.

Ground for the Bowl was broken on June 23d, 1913, by President Hadley, of the University, turning the first sod. The real construction was begun during the following month by first removing the loam from the site and from the adjoining area which required grading. The black and yellow loam was stored in separate piles and saved for resurfacing the grounds after the completion of the structure. The average depth of this preparatory stripping was about 22 in. For removing the loam, on short hauls up to about 100 ft., drag-scrapers were used; on hauls from about 100 to 250 ft., wheel scrapers; and for long hauls, bottom-dump wagons.

Several plans for placing the material in the embankment were considered by the contractor, but the one finally adopted for handling the greater part of it was the use of two drag-line scrapers running on adjustable cables and operated from two towers, 85 ft. high, by two 12 by 16-in. double-drum engines, supplied with steam from two 125-h.p. locomotive boilers. The towers ran on a four-rail elliptical track laid around the outside of the Bowl. One end of the carrying cable was fastened to a "deadman" on the opposite side of the field from the tower; the other end ran over a pulley at the top of the tower and was fastened to one of the drums of the engine, by which means it could be regulated for filling or emptying the bucket, the cable being slackened for filling the scraper and then tightened for dumping it. The second drum was used for hauling the scraper up the slope; it ran back to the filling point by gravity.

As the two scrapers, working night and day, did not remove the material rapidly enough to indicate the probable completion of the contract within the time specified, two $\frac{5}{8}$-yd. rotary steam shovels were started, in order to expedite the work, and these filled bottom-dump

wagons. The teams with their loads were then drawn to the top of the embankment by a portable hoisting engine working there, and the material was distributed as desired.

As it was impracticable to roll the embankment below the level of the tops of the tunnels, dependence for packing the material in this portion of the work was placed on such consolidation as could be obtained by the liberal use of water, and such tamping as was done by the teams being driven over it. Streams of water were always kept playing on the embankment where material was being deposited, and the portions next to the tunnels and the retaining walls were generally sluiced into place from piles deposited by the teams or scrapers.

Above the tops of the tunnels, the material deposited by the scrapers was left in ridges extending across the embankment; that from the wagons was left in scattered piles; in each case sufficient material was placed to make layers 6 in. deep when leveled down. The leveling was done with horse-drawn scrapers. The material was thoroughly watered and then rolled, first with a grooved and then a smooth roller, one following in the track of the other. The rollers weighed 800 lb. per ft. of length, and, by using them alternately, the effective weight was practically doubled. Each roller was drawn by four horses, and each passed four times over the entire area being rolled. The embankment was kept about 1 ft. wider than the theoretical lines in order to insure the compacting of the material out to the edges of the finished fill.

To ascertain the settlement in the embankment, after its completion thirty-one benches were established around the top. Each bench consisted of a mass of concrete in which was inserted a $\frac{1}{2}$-in. square steel rod, placed about 4 ft. below the surface, the end of the rod terminating a few inches below the surface. Levels taken on these benches have shown that, after a lapse of 2 years, the average settlement has been only about $\frac{1}{4}$ in., and the maximum settlement at any bench about $\frac{1}{2}$ in. About one-half of this settlement occurred within the first month after the establishment of the benches.

A comparison of the volume of the embankment with that of the excavation shows that the material in the former is nearly 7% more dense than that of the natural bank. It is probable, therefore, that the slight settlement which occurred was caused by the compression of the underlying material, due to the added weight of the fill, rather than by any subsequent consolidation of the embankment itself.

The favorable results obtained in securing a solid embankment were probably due to the character of the material of which it is composed and the method of placing it. The material was sand and gravel, almost entirely free from clay, loam, or other substance which would retain water. By the alternate use of the two kinds of roller, not only was a downward pressure exerted, but, at the same time, a lateral motion was given to the particles of sand, thereby tending to bring them into close contact with one another.

Water for sprinkling the embankment and mixing concrete was obtained from a group of driven wells at the foot of the bluff, at the edge of the marsh, and was distributed by a 4-in. pipe, laid around the outside of the Bowl, with hose connections at frequent intervals. The water from the wells was pumped by a single-acting, triplex pump, operated by an electric motor. The contractor was required to furnish at least 150 gal. of water per min., and this quantity was delivered continuously, day and night, including Sundays and holidays, while the embankment was under construction. A connection was also made with the mains of the New Haven Water Company, in order to insure a constant supply in case of a failure of the wells or a break down of the machinery.

As the drag-line scrapers left the inner face of the slope in a very irregular condition—a series of deep gullies and sharp ridges—the contractor devised a leveling scraper for smoothing up the work. This consisted of a frame, about 6 ft. square, of 12 by 12-in. timbers, the front faces of which were shod with steel plates. This frame was attached to the drag-line by a bridle, and was drawn up the slope in the same manner as the excavating scrapers. The final trimming of the slope was done by hand shoveling.

Two mixers were used for supplying concrete for the tunnels. For the footings, there was a portable, ½-yd., gasoline mixer at the inner portal of each tunnel. This delivered its material into cars running on a track laid between the footings, from which the concrete could be dumped into the forms on either side as desired. An electrically operated ¾-yd. mixer near the center of the field was used for mixing the concrete for the portion of the tunnels above the footings. The concrete was conveyed on cars running on an industrial railway track laid on the ground from this mixer to a point near the inner portal of the tunnels, then up an inclined trestle to their top and then on

timbers laid on the side forms. From the mixer to the foot of the incline the cars were hauled by a horse, and for the remainder of the distance by a hoisting engine outside the Bowl.

For building the outside retaining wall and the smaller gate-house walls, there were two ½-yd. mixers on an elevated trestle built on the site of the gate-house. These delivered the concrete into bottom, side-dump cars running on an industrial railway laid on top of the wall forms. For the large gate-house walls, a mixing plant was established near the wall, and the concrete was delivered into a 120-ft. elevator, from which it was distributed by chutes. The same plant also made the concrete for the inner retaining wall and the facing steps. For this work the concrete was delivered by the chutes into the bottom, side-dump cars running on a portable track laid just above the inner portals of the tunnels; from them it was distributed, by portable chutes laid on the ground, directly into the forms, the slope of the bank being steep enough to cause the concrete to flow in the chutes. The greatest distance through which concrete was carried by the chutes, in a single run, was about 250 ft.

For handling sand and stone at the two main mixing plants, elevated bins were constructed so that cars or trucks could be run on top of them and deliver material without shoveling. Chutes at the bottom of the bins delivered material into cars which were divided by partitions to hold the required quantity of each ingredient for one batch. From the cars the materials were dumped directly into the mixer.

All the sand for the work was obtained at the site. Though an abundance of gravel, of a size suitable for the concrete, was found in the excavation, only a small quantity of it was used in some of the footings, as it contained a considerable proportion of sandstone pebbles which it was feared would absorb moisture and disintegrate under the action of frost if exposed to the elements. Most of the stone used was crushed trap rock. This was brought from a quarry about 2½ miles distant by two motor trucks: a 5-ton truck which not only carried its own load but also hauled 3 tons in a trailer; and a 3-ton truck. The price paid for hauling the stone was 27 cents per ton.

The cement used in the work was furnished by the contractor, but was paid for as a separate item, thereby enabling the engineer to change the proportions of the ingredients in the concrete, as seemed desirable,

without causing any dispute as to the quantity used. The cement was all tested at the mill by agents of testing laboratories.

Comparison with Other Stadia.

The Bowl is believed to have the largest seating capacity of any structure of the kind in existence, and to have been exceeded by only one of ancient times—the Circus Maximus of Rome, which is stated to have seated 380 000 persons. Statements regarding the capacity of the Roman Colosseum, the most widely known of the ancient amphitheaters, vary widely from 45 000 to 100 000. It is stated that in the ancient amphitheaters only the classes were provided with seats, the masses being obliged to stand.

With the seats removed, the Bowl could accommodate comfortably a standing audience of about 125 000. The Athens Stadium seated 50 000; the stadium of the College of the City of New York seats about 10 000; the Syracuse and Tacoma Stadia each accommodate about 20 000; the Boston baseball stands, 24 000; the double-deck stands at the New York Polo Grounds, about 28 000; the Harvard Stadium, as first constructed, seated 23 000, but, with additions and with temporary seats at the open end, it can accommodate about 45 000; the new Princeton Stadium seats about 41 500; and the Bowl about 61 000.

Though the Bowl is the largest of the modern stands, it is also, probably, the cheapest per sitting. Though the actual cost of other stands is not accurately known, the contract price, as reported in engineering and other journals, gives the average cost per sitting as ranging from about $36.00 for the stadium of the College of the City of New York down to about $8.50 for the Princeton Stadium. The cost per sitting for the Bowl, as constructed, including the grading of the grounds around it, was about $7.35. The cheapness of the Bowl was partly due to the exceptionally favorable conditions at the site for building this kind of a structure. This was a level plain elevated about 40 ft. above a marsh from which it was separated by a steep bluff, thus affording perfect drainage at a minimum of expense. The material was clean sand and gravel extending to an unknown depth, easy to handle, and ideal for making a solid embankment.

Previous to the building of the Bowl, the materials used in the construction of grand-stands were wood, steel, reinforced concrete, or a combination of the two latter, and, in the case of ancient struc-

tures, masonry. Though wood is a suitable material for stands of small size, it is entirely unsuited for large ones, owing to rapid deterioration when exposed to the weather and liability to destruction by fire. Though monumental structures of masonry, like the Roman Colosseum, were possible with the slave labor available in the first centuries of the Christian era, it would be impracticable to finance such an undertaking at the present time. Steel and reinforced concrete are, from an engineering standpoint, more practical building materials for structures of this kind.

Maintenance charges are an important factor to be considered in planning for a steel stand of large size. Whether temperature changes and frost action will injuriously affect skeleton structures of the size of the large modern stadia, when built of reinforced concrete, either alone or in combination with external steel, is an interesting question yet to be answered. Apparently, the only portions of the Bowl which will require material expense for maintenance are the benches, as the remainder of the structure is practically a portion of the earth's crust—a low hill surrounding a small valley.

One advantage of this form of construction, besides its cheapness, is the facility with which the plastic materials, earth and concrete, may be adapted to the formation of curved shapes, thus, without any material expense, permitting of curved instead of straight sides, which were such an objectionable feature of the old wooden stands at Yale.

Another advantage is that a stand can be increased in size without materially affecting any part of the work already done. By building a balcony over the promenade and the portion of the seats above the tunnel portals, the seating capacity of the Bowl can be increased to about 100 000 without affecting any portion of the structure other than by the removal and replacing of a few blocks of concrete to permit the building of proper footings for columns, the embankment being sufficiently stable for the support of the additional structure.

With nearly 61 000 seats for spectators provided, it was thought the stand would be large enough to meet any possible demand for accommodations from those interested in football, but when the time limit expired for the receipt of applications for tickets for the first game in the Bowl—Yale *vs.* Harvard in 1914—it was found that more than 80 000 had been received. To meet this demand, so far as possible, extra seats were erected over the promenade, so that the number of

people who witnessed that game was probably a little more than 70 000. In spite of this vast number, in 12 min. from the close of the game, the Bowl was practically empty of people, and this time might have been shortened by about 5 min. had not the spectators tarried to witness the celebration of the victory, on the gridiron, by the partisans of the winning team. Although the Bowl was emptied in such a short time, there was no congestion at any point except in the aisles, as the capacity of the tunnels to handle the crowd was greater than that of the aisles, and the thirty-two tunnels distributed the crowd over such a large area, the inner circumference of which was a little more than $\frac{1}{2}$ mile, the distance around the outside of the Bowl, that there was plenty of room for the free movement of the people.

Adaptation for Other Purposes.

Although the Bowl was built for football alone, its remarkable acoustic properties render it admirably fitted for the production of dramatic events on a large scale, and two such have already been held there with pronounced success: the Greek play, "Iphigenia in Taurus", given by Mr. Granville Barker under the auspices of the Yale Dramatic Association, and the opera "Die Walküre", by the Metropolitan Opera Company, under the auspices of the Yale School of Music. For these performances, the stage was erected near the center of the field, and a section of about 25 000 seats was set apart for the spectators at one end of the amphitheater.

To celebrate the two-hundredth anniversary of the removal of Yale College to New Haven, a pageant is now being prepared in which it is expected that about 8 000 performers will participate.

Under favorable atmospheric conditions, when there are only a few people in the Bowl, a whisper spoken at the center of the field can be distinctly heard at the tunnel portals; and a conversation, in an ordinary tone of voice, can be carried on between persons stationed on opposite sides of the amphitheater. At the performances mentioned, even the softest passages could be plainly heard in the most remote seats reserved for spectators. With the seats removed, a person with a good voice and accustomed to public speaking could, undoubtedly, address an audience of 125 000 and be heard distinctly by every one.

The following are some of the principal items of construction:

Earthwork	331 000	cu. yd.
Mass Concrete	16 000	" "
Concrete facing	111 000	sq. ft.
Wood facing	145 000	" "
Granolithic pavement	35 000	" "
Cement	26 000	bbl.
Steel for reinforcement	482	tons.
Wood benches	18	miles.
Turf laid	161 000	sq. ft.
Sewers	6 400	lin. ft.
Water mains	4 700	" "
Area covered by structure, about	12½	acres.

The Bowl was built by the Yale Committee of Twenty-one, Incorporated, Mr. Thomas DeWitt Cuyler, Chairman, with Mr. David Daggett, Chairman of the Structures Committee. Edward G. Williams, M. Am. Soc. C. E., was Advisory Engineer, and Mr. Donn Barber, Consulting Architect. The writer was the Designer and Engineer in charge of construction. Mr. Joseph H. Mulvey was Chief Inspector. James B. French, M. Am. Soc. C. E., served as Consulting Engineer for a few months at the beginning of the work, and Thomas C. Atwood, M. Am. Soc. C. E., as Construction Manager for a few months at the end. The Sperry Engineering Company, of New Haven, Conn., was the contractor for the whole work.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

TEMPERATURE STRESSES IN A SERIES OF SPANS

Discussion.*

By Tresham D. Gregg, Assoc. M. Am. Soc. C. E.†

Tresham D. Gregg,‡ Assoc. M. Am. Soc. C. E. (by letter).§—The writer quite agrees with Mr. Martin that the stresses found are unusually high. In defense, however, of his selection of an example to illustrate the principles involved, he wishes to say that it is his experience that skewed piers are frequently necessary, and that massive piers are sometimes more economical than light, flexible bents, and always considerably safer where there is danger from collision with derailed cars or locomotives. It is freely admitted that the theory developed has small practical application, except in the type of bridge selected. Mr. Gregg.

The writer also agrees with Mr. Martin's "guess" that the distortions involving least work will be in a direction oblique to the axis of the bridge. The calculation of the true stresses in such a combination would be extremely complicated. In order to find the true state of stress in all the members—in the case where all supports are fixed—consideration must be given to the work of expansion of the several spans against piers which have a variable moment of inertia, depending on the extent to which they yield in a lateral direction; to the bending of the spans, particularly the end spans, due to the lateral movement of the piers; and to the work of torsion of the piers and bending of the spans, due to the change in angle of skew, brought about also by the lateral deflection of the piers.

* Discussion of the paper by Tresham D. Gregg, Assoc. M. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† Author's closure.

‡ Minneapolis, Minn.

§ Received by the Secretary, September 14th, 1916.

Mr. Gregg.

The writer has reason to think that this lateral movement of the piers is a very minute quantity. If it should amount to one-half of what it would be if the spans were pivoted on the piers and the abutment ends were free to move, bending stresses in the span would be set up, which would be, if anything, greater than the axial stresses calculated under the original assumption, and bending stresses in the piers—perhaps one-fourth in amount of those tabulated in this paper—would nevertheless be combined with high torsion stresses, leaving the situation, in the writer's opinion, about as bad as before.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

DESIGNING AN EARTH DAM HAVING A GRAVEL FOUNDATION, WITH THE RESULTS OBTAINED IN TESTS ON A MODEL.

Discussion.*

By Joseph Jacobs, M. Am. Soc. C. E.

Joseph Jacobs,† M. Am. Soc. C. E. (by letter).‡—This paper is of interest because it deals with an important engineering subject, concerning which there is all too little reliable information on which definite theory and judgment may be predicated. The author is entitled to credit for assembling the results of these tests for the use of the Profession, and for his frankness in presenting his interpretation and application of the facts disclosed. Mr. Jacobs.

The writer believes that the author failed to reach certain important conclusions, apparently fully warranted by the tests, and that in some respects his deductions as to the theory of underground water movements are fallacious. Particularly does he believe that the tests do not justify the conclusion, reached by the author, that the "line of creep" theory has been disproved.

In describing the initial seepage test in the 30-in. cylindrical tank (page 325§), the author states:

"A valve at the bottom held back the water until the pore spaces were completely filled; then the valve was opened, and after a few minutes the relative elevation of the water in the two tubes became

* Discussion of paper by James B. Hays, Jun. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† Seattle, Wash.

‡ Received by the Secretary, October 2d, 1916.

§ *Proceedings*, Am. Soc. C. E. for March, 1916.

Mr. Jacobs. constant. The difference in elevation determined the loss of head, and from this the hydraulic gradient was computed."

* * * * * * *

"With 6 in. of water on the soil surface, and 8 in. of soil above the upper tube, the loss of head was 1 ft. in 9."

* * * * * * *

"Having determined the hydraulic gradient of the underground material, a trial design was made to find what dimensions would be necessary in a dam constructed wholly of gravel."

These quotations, it seems to the writer, disclose a fundamental error in the author's application of his test. It will be noted that there is no mention of the quantity of seepage flow, and, as seepage flow and hydraulic gradient are inter-dependently related, the mention of one means nothing unless there is also included a definition of the other. The hydraulic gradient of 1 : 9, as found by the author, would appear to be a purely fortuitous result, for, with a variation in the size of valve opening (if it is less than the capacity of the gravel), and with variation in the depth of water above the soil surface, the ratio of loss of head to length of travel may be made to vary indefinitely. The maximum permissible limit of this ratio is that at which the seepage loss becomes prohibitive as to quantity, or at which the induced velocities are such that erosion or piping is threatened as a forerunner of the ultimate failure of the dam. It may be that the author decided that these requirements had been met in his hydraulic gradient of 1 : 9, but there is nothing in the text indicating this special consideration, nor do the seepage tests on the model dams seem to warrant such a decision.

It will be noted from the Second Series of Tests, which relate to the model from which the final dam was designed, that under a 10-in. head there was a mean seepage loss of approximately 0.0025 cu. ft. per sec. per lin. ft. of model dam. Bearing in mind that the model dam was built on a scale of 1 : 120 as compared with the final dam, and assuming, for the moment, that the hydraulic gradients and therefore the seepage velocities would be identical in the two, it follows that the seepage loss for the actual dam, under a condition of full reservoir, would be 360 cu. ft. per sec., made up as follows:

400 lin. ft. of dam under	100 ft. head, yielding	.....120 cu. ft. per sec.
1 600 " " " " "	100 to 0 ft. head "	.....240 " " " "
Total rate of seepage flow at full reservoir		..........360 cu. ft. per sec.

This 360 cu. ft. per sec. would be further increased by reason of the hydraulic gradient in the actual dam being greater than that in the model. In comparing ratios of head to length of water travel, it is the friction head and not the total head that must be considered. In the model dam the 10 in. total head is greatly depleted by entry and exit

heads, thus leaving a greatly reduced head available for friction losses, whereas, in the actual dam of 100 ft. head, the same quantitative depletion for entry and exit heads has relatively slight effect on the remaining friction head. Mr. Jacobs.

So great a loss as 360 cu. ft. per sec. from any reservoir would, of course, be prohibitive, even in the absence of any danger of undercutting the dam, and it must be assumed that the figures given in the paper are in error or that the author failed to apply the apparently clear inference to be drawn from his tests, which latter seems to be untenable because the tests appear primarily to have been suggested by the seepage difficulties encountered in the original dam. It would be interesting to have now a record of the actual behavior of the dam, as to seepage losses, if there has been opportunity for test since construction.

Concerning entry head and exit head there is indication that the total head is affected by these elements, and it is this fact that renders difficult of interpretation the results obtained from experiments with small model dams, for in such dams the combined entry and exit heads may indeed form a relatively large part of the total head, though in dealing with full-sized dams they would form a relatively small or negligible part. To determine entry and exit heads from any set of tests, such as those by the author or by Mr. Colman,* we must first ascertain the friction head, and this in turn depends on the assumption as to line and resultant length of water travel along any film or differential element of flow. A critical examination of these tests shows a rate of loss of head due to friction that is not uniform per distance traveled, as measured between observed tubes. This disparity is due no doubt to variation in porosity and other mechanical elements of the pervious medium, and probably to some extent to observational errors, for it has been well established that, for an unchanging medium of this character, the rate of friction head consumption will be uniform. On the scheme of underground water movement, as hereinafter explained, the writer finds values of entry and exit heads in the Hays and Colman tests varying as follows:

In the Hays tests, with a total head of 10 in., entry heads varied from — 0.90 to + 5.98 in., the mean being + 5.5 in.; and exit heads from — 2.26 to + 0.45 in., the mean being — 0.9 in.

In the Colman tests, with an average total head of 54 in., entry heads varied from — 1.08 to + 21.36 in., the mean being + 7.0 in.; and exit heads from — 7.32 to + 13.08 in., the mean being + 3.4 in.

Because velocity is a function of all the elements which characterize the medium through which the water moves, it was thought that some

* *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 421.

Mr. Jacobs.

relationship might be established between entry head and entry velocity, and exit head and exit velocity. The graphic method was used, but there was such lack of consistency in the results deduced from the tests that no dependable curves could be platted. Nor was this lack of consistency due to the particular scheme of water movement assumed, for other assumptions as to line and length of water travel showed similar inconsistencies. In the absence of more extensive data than we now have, we may only say at this time that there is entry head and exit head of uncertain amounts which must be reckoned with in experiments on small models, but which are negligibly small in dealing with full-sized dams.

All the formulas for the flow of water through soils are of the general form, $Q = c \frac{h}{l} a$, in which

$Q =$ discharge;

$a =$ area of cross-section;

$\frac{h}{l} =$ ratio of loss of head due to friction to length of water travel;

and $c =$ a variable coefficient, dependent on water temperature, porosity, and mechanical analysis of the soil.

Water will follow the line of least resistance, and therefore that form of section and route of water movement will obtain which, for a given head, will afford a maximum discharge, or which, for a given discharge, will consume the minimum head. These conditions, as will readily be seen from the foregoing equation, in which c for any specific case is a constant, will be satisfied when $\frac{l}{a}$ is a minimum; and, in studying seepage and pressure problems, with respect to dams on porous foundations, we must first ascertain the form of section and route of water travel which renders $\frac{l}{a}$ a minimum.

It cannot be assumed that the water will be drawn from an indefinite distance up stream, nor released throughout an indefinite distance down stream, from the dam, for, if that were the case, Q would approach its minimum rather than its maximum, and $\frac{l}{a}$ would approach its maximum rather than its minimum value.

There may be, and doubtless is, some seepage draft from points far above, and seepage delivery to points far below, the dam, but the quantities would be negligible in comparison with the main body of seepage water, which, in the writer's opinion, based on mathematical analysis, would necessarily be drawn from, and delivered to, points in the immediate vicinity of the dam. The lengths of river bed over

Mr. Jacobs.

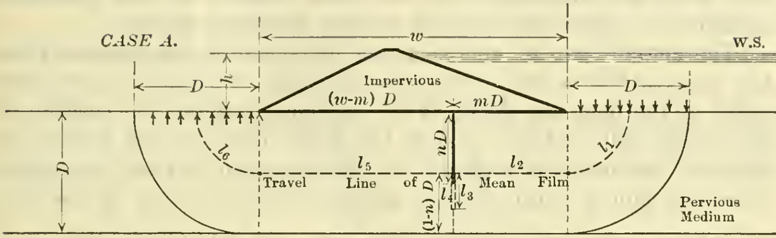

FIG. 19

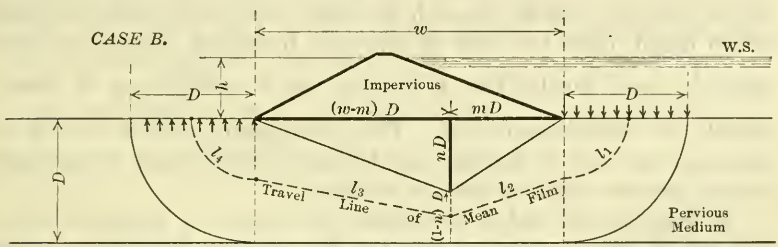

FIG. 20

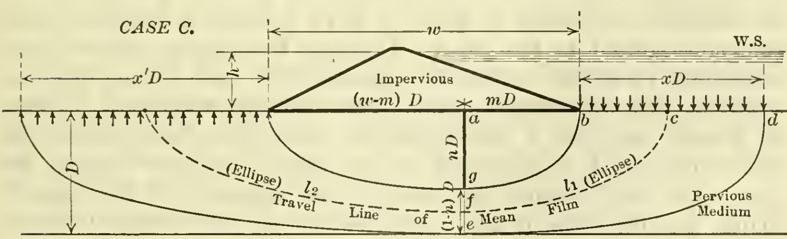

FIG. 21

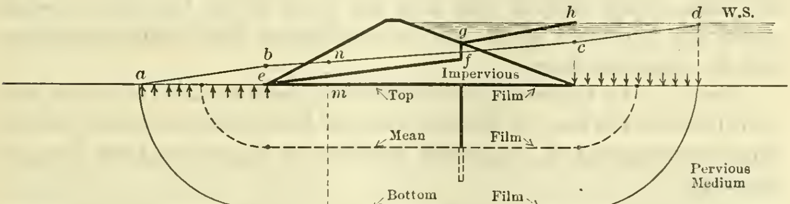

FIG. 22

Mr. Jacobs. which water draft and water release are operative, with respect to any dam, are important, because these lengths fix the hydraulic gradients on which pressure and seepage discharge depend.

The actual form of approach and exit channel for seepage, from free water above to free water below the dam, will depend on the base width of the dam, the depth of the pervious medium, the position of the cut-off wall, and the ratio of the depth of the cut-off wall to the depth of the pervious medium. If the approach is from free water above the dam to a full vertical section beneath the heel of the dam, the writer finds that, whatever its form, the minimum value of $\frac{l}{a}$ occurs when the distance up stream from the dam equals the depth of the pervious medium beneath the dam; that, of the various curves which might define the form of approach, the ellipse affords the minimum $\frac{l}{a}$; and, finally, that the circle, as a special form of ellipse, affords the absolute minimum. This, then, means a circle having its center at the heel of the dam and having a radius equal to the depth of the pervious medium beneath the dam.

In Figs. 19, 20, and 21 are shown three forms of seepage channel, any one of which, assuming that the dam itself is impervious, might be the actual for a particular case, depending on the position of the cut-off wall and other conditions, as already stated. These will now be examined: Referring to Figs. 19 to 21, consider a section of unit thickness normal to the paper. Dividing the seepage channel into longitudinal sections, as obviously demanded by their change in cross-sectional form, the mean lengths of these sections would be l_1, l_2, etc., as shown, and, for a unit thickness, their mean areas would be some function of D, the depth of the pervious medium beneath the dam. The total seepage flow would be the aggregate of the approximately parallel films of flow, each film having its individual length, individual discharge, and individual hydraulic gradient. The mean film would control as to the total seepage loss, and the hydraulic grade line of the top film would control as to the pressure on the base of the dam, except that, at and near the lower toe of the dam, in some cases, the hydraulic grade line of the bottom film might control, as will be explained later.

Case A.—In this case the seepage flow occupies the full prism section between the base of the dam and the base of the pervious stratum. The mean lengths of its several sections, as is obvious from Fig. 19, would be:

$$l_1 = l_6 = 0.7854\ D,\ l_2 = m\ D,\ l_3 = l_4 = \frac{n\ D}{2},\ l_5 = (w - m)\ D.$$

The mean areas of these sections would be: Mr. Jacobs.

$$a_1 = a_2 = a_5 = a_6 = D;\ a_3 = a_4 = \frac{D + (l - n)\,D}{2} = \frac{D}{2}\,(2 - n).$$

From the original equation for seepage flow, $Q = c\,\frac{h}{l}\,a$, we obtain, $h = \frac{Q}{c} \times \frac{l}{a}$; or, for any section, n, $h_n = \frac{Q}{c} \times \frac{l_n}{a_n}$. The total head, therefore, would be, $h = h_1 + h_2 + \ldots.\ h_6$

$$= \frac{Q}{c}\left(\frac{l_1}{a_1} + \frac{l_2}{a_2} + \ldots.\ \frac{l_6}{a_6}\right) = \frac{Q}{c}\left(1.5708 + p + \frac{2\,n}{2 - n}\right).$$

Case B.—In this case (Fig. 20) the seepage flow occupies the wedge-shaped sections beneath the dam, and, in the space between the base of the dam and the top of the seepage channel, there would be dead water, or approximately dead water. For this case we would have:

$$l_1 = l_4 = 0.7854\ D,\ l_2 = \frac{D}{2}\ \sqrt{4\,m^2 + n^2},\ l_3 = \frac{D}{2}\ \sqrt{4\,(w - m)^2 + n^2}.$$

$$a_1 = a_4 = D,\ a_2 = a_3 = \frac{D}{2}\ (2 - n).$$

$$h = (h_1 + h_2 \ldots.\ h_4) = \frac{Q}{c}\left(\frac{l_1}{a_1} + \frac{l_2}{a_2} + \ldots.\ \frac{l_4}{a_4}\right)$$

$$= \frac{Q}{c}\left(1.5708 + \frac{\sqrt{4\,m^2 + n^2} + \sqrt{4\,(w - m)^2 + n^2}}{2 - n}\right).$$

Case C.—In this case (Fig. 21) the form of approach and exit is defined by ellipses, as shown, and, as in the previous case, the space between the base of the dam and the top of the seepage channel would be approximately dead water. The distance up stream from which seepage water would be drawn is determined as follows:

The mean film, $l_1 = fc$, is the quarter circumference of an ellipse the major and minor semi-axes of which are $a\ c = \frac{D}{2}\ (2\ m + x)$ and $a\ f = \frac{D}{2}\ (1 + n)$, respectively, and its length, according to the usually accepted approximate formula, would be

$$l_1 = \frac{\pi\ D}{4}\sqrt{\frac{(2\,m + x)^2 + (1 + n)^2}{2}}.$$

The cross-sectional area of the seepage channel, for unit thickness, would vary from $bd = xD$ to $ge = (1 - n)D$, and the mean area would be the area, $bdeg \div l_1$, the area, $bdeg$, being equal to the differ-

Mr. Jacobs. ence between the areas of the elliptical quadrants, *aed* and *agb*. The area, $bdeg = A = \frac{\pi D^2}{4}(m + x - m\,n)$, and $a_1 = \frac{A}{l_1}$. Therefore,

$$h_1 = \frac{Q}{c} \times \frac{l_1}{a_1} = \frac{Q}{c} \times \frac{l_1^2}{A} = \frac{Q}{c} \times \frac{\pi}{8}\left(\frac{(2\,m + x)^2 + (1 + n)^2}{m + x - m\,n}\right) \ldots (1)$$

To find the minimum value of $\frac{l_1}{a_1}$, differentiate and place the first differential coefficient equal to zero, thus,

$$\frac{\delta\, h_1}{\delta\, x} = \frac{Q}{c} \times \frac{\pi}{8}$$

$$\left(\frac{2\,(m + x - m\,n)\,(2\,m + x) - ((2\,m + x)^2 + (1 + n)^2)}{(m + x - m\,n)^2}\right) = 0.$$

Clear of fractions, transpose, and reduce, and we have,

$$x^2 + 2m\,(1 - n)x = (1 + n)^2 + 4m^2n.$$

Complete the square, and we have,

$$x^2 + 2m\,(1 - n)x + m^2\,(1 - n)^2 = (1 + n)^2\,(1 + m^2).$$

Therefore,

$$x + m\,(1 - n) = \pm\,(1 + n)\,\sqrt{1 + m^2},$$

whence $$x = (1 + n)\,\sqrt{1 + m^2} - m\,(1 - n),$$

and this critical value of x proves to be the minimum rather that the maximum value of $\frac{l_1}{a_1}$. We would also have,

$$x' = (1 + n)\,\sqrt{1 + (w - m)^2} - (w - m)\,(1 - n).$$

Applying these values of x and x' to Equation (1), and reducing, we would have

$$h = h_1 + h_2 = \frac{Q}{c}\left(\frac{l_1}{a_1} + \frac{l_2}{a_2}\right)$$

$$= \frac{Q}{c} \times \frac{\pi}{4}(1 + n)\left[w + \sqrt{1 + m^2} + \sqrt{1 + (w - m)^2}\right].$$

Which one of the foregoing three cases would obtain for any actual dam would depend on the values of m, n, and w, but it would always be that one case, or that combination of the several cases, which would render $\frac{l}{a}$ a minimum. To determine this for any particular set of conditions is a simple computation, but a tabulation for varying values of m, n, and w, shows that, in most instances, Case A will obtain, and that Case C obtains only when m, n, and w are small. As between

Cases A and B, when m is less than $0.66\frac{2}{3}$, the wedge affords the minimum $\frac{l}{a}$; when m is greater than 1.00, the prism affords the minimum $\frac{l}{a}$; and between these values of m, it may be either wedge or prism, depending on the value of n. Mr. Jacobs.

Now consider the question of the hydraulic upward pressure against the base of the dam: If the total head is known (as it would be in the cases considered), then its apportionment among the several sections of the seepage channel results from the general equation,

$$h = (h_1 + h_2 + \ldots . h_n) = \frac{Q}{c}\left(\frac{l_1}{a_1} + \frac{l_2}{a_2} + \ldots . \frac{l_n}{a_n}\right),$$

and would be as $\frac{l_1}{a_1} : \frac{l_2}{a_2} : \ldots . \frac{l_n}{a_n}$.

This apportionment, it will be noted, is independent of Q and c, for Q is necessarily the same for all sections, and c, too, is a constant, if the pervious medium be regarded as homogeneous throughout. If the medium is not homogeneous, and c is variable from section to section, then that factor would need to be retained in the computation, but the apportionment of head would still be fully determinable, if c were known for each section. This lack of perfect homogeneity tends to confuse the results in any study of the laws of underground water movement, and it is no doubt partly responsible for the variations and apparent disparities noted in the Hays' experiments.

In the top film of a seepage channel, the form of the channel having been determined, the lengths, l_1, l_2, etc., become known, and, as for the areas, a_1, a_2, etc., it must be assumed that, in this differential element of flow, the differential areas of the several sections bear the same relationship to each other as do the like whole areas of the whole seepage channel. The relative values, $\frac{l_1}{a_1}$, $\frac{l_2}{a_2}$, etc., thus become known, and the apportionment of the total head among the several sections of the top film, according to the method outlined in the previous paragraph readily follows. From this determination of the heads, h_1, h_2, etc., the hydraulic grade line for the top film (and in similar manner for the bottom film) can be constructed, whence the computation for the hydraulic upward pressure proceeds by the proper evaluation of the area included between base of the dam and the higher of these grade lines; that for the bottom film, however, is subject to slight modification.

Referring to Fig. 22, it will be noted that *abcd* is the hydraulic grade line for the bottom film, and *efgh* for the top film, and that, for the section of the dam below the cut-off, the former appears to con-

Mr. Jacobs. trol as to the hydraulic upward pressure against the base of the dam. This is not necessarily so, however, nor do these hydraulic grade lines indicate the exact plane to which water would rise if the down-stream portion of dam were pervious, for there would be loss of head and pressure between the film considered and the final water plane, wherever it might be. The ordinate, *m n,* for instance, measures the head or hydraulic pressure of the bottom film at the point, *l,* whereas the actual pressure at *m* would be less than *m n* because of the loss of pressure between *l* and *m,* and because otherwise the water would tend to find escape in that direction rather than along the course, *lka.* The actual pressure line for the base of the dam due to the bottom film is probably little, if any, above that due to the top film, but the writer does not, at this time, know just how it can be located with assurance of entire accuracy.

It will be noted that the validity of the "line of creep" theory is herein recognized, but that it does not have universal application. It obtains with respect to Case *A* when considering hydraulic pressures against the base of the dam, but does not apply to Cases *B* and *C.* In his examination of the author's tests (Case *A* applies), the writer finds nothing to upset the general theory developed in the foregoing, but, on the contrary, finds some confirmation in the fact that the average maximum departure of the observed from the writer's computed hydraulic grade line was only $\frac{3}{4}$ in. When it is considered that the author's tests show a computed variation in entry head of from — 0.90 to + 5.98 in., and in exit head of from — 2.26 to + 0.45 in., a departure of $\frac{3}{4}$ in. from a computed grade line should occasion no surprise. The uncertain effect of capillarity, undefined entry and exit resistances, variations in the mechanical analyses of the soil, and slight observational errors, would readily account for so inconsiderable a discrepancy.

On the whole, it may be questioned whether results from tests on such small-size models are of great value. The disturbing and relatively important effect of exit and entry heads, the possibility of inadequate box length to provide free approach and free exit of the seepage water, and other inherent limitations, certainly make the correct interpretation of the results extremely difficult. In the writer's opinion, the only acceptable confirmation of any theory as to the movement of seepage waters beneath dams, and the effect of cut-off walls thereon, must come from observation of full-sized structures actually built.

In closing, the writer would add that the following necessary conclusions are deduced from the general theory herein developed:

1.—That the form of computation for determining discharge and hydraulic grade line are similar to and practically as simple

as those for pipe lines. With a reasonably accurate selection of the coefficient, *c*, in the first general formula, a reasonably accurate discharge, *Q*, can be predicted for any head of water above the dam, and a reasonably accurate hydraulic grade line can be platted for computation of pressures. Mr. Jacobs.

2.—That the cut-off wall must extend practically to an impervious stratum in order to reduce seepage loss appreciably. This fact is important in cases where seepage, by reason of its quantity, or its possible erosive action, must be considered.

3.—That, from considerations of both seepage loss and reduced hydraulic pressure on the base of the dam, the cut-off wall should be as near the heel of the dam as the local physical conditions will permit.

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PAPERS AND DISCUSSIONS

TUNNEL WORK ON SECTIONS 8, 9, 10, AND 11, BROADWAY-LEXINGTON AVENUE SUBWAY, NEW YORK CITY

Discussion*

By Messrs. Maurice Griest, John H. Madden, and Robert H. Jacobs.

Maurice Griest,† Esq. (by letter).‡—This paper describes the construction of the rock tunnels in Lexington Avenue from 57th Street to 102d Street. It has been prepared, however, from the point of view of the construction engineer, rather than that of the designer, therefore some special features of the design will be presented, particularly of that portion from 97th Street to 102d Street, where the structure changes from a double-deck tunnel to a four-track tunnel on one level. Mr. Griest.

Two features seem worthy of brief mention: First, the flat-roof construction with transverse beams and concrete jack-arches and the reasons for its use; and second, the method of reinforcing the structure after the steel therefor was delivered, in order to provide for materially heavier loads than were contemplated originally.

The original design for this portion contemplated the use of concrete arches—twin tubes between 97th and 100th Streets as the local tracks spread out, and four single-track tubes from 100th to 102d Street as the grades approach. In the former case, the clear span varied from 14 to 30 ft.; in the latter case, the spans were uniformly 14 ft. The principal reason for adopting the arch form of construction in preference to the ordinary subway construction, was the greater ease in placing the concrete in the arch form than in the flat roof with smaller clearance above.

* This discussion (of the paper by Israel V. Werbin, Assoc. M. Am. Soc. C. E., published in August, 1916, *Proceedings,* and presented at the meeting of September 20th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

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‡ Received by the Secretary, September 20th, 1916.

Mr. Griest. It was soon apparent that it would be desirable, on account of the condition of the rock, to construct one track at a time. To do so with the original construction, it would have been necessary to leave the centers in place in one arch until the adjacent arch was poured and packed to rock. Therefore, the ordinary flat roof construction with transverse beams, 5-ft. centers, was substituted, the steelwork being arranged to permit the construction of the center express tracks in advance of the excavation for or construction of the local tracks.

Between 100th and 102d Streets, the roof in general for the ordinary 14-ft. width consisted of a 20-in., 80-lb. beam supported between the tracks by 6-in. plate and angle columns, and at the sides by 12-in., $31\frac{1}{2}$-lb. wall beams, designed for both roof load and side-wall pressure. This roof could carry safely the weight of 12 ft. of rock above it. It was expected that the rock would be sound enough to arch over, so that in no case would there be a weight greater than the foregoing carried by the roof. It was necessary, later, to increase the strength of the roof, for two reasons: first, at 102d Street, on account of the poor rock, open-cut excavation was extended beyond the original portal location, so that the maximum depth of fill over the roof was increased to depths varying from 28 to 38 ft. The roof, therefore, designed to carry 12 ft. of rock, was now to support from 28 to 38 ft. of back-fill. As described in the paper, the rock in some cases broke out 12 ft. beyond the neat line of excavation, the excess excavation being refilled with hand-packed stone or concrete. In other cases, the rock was poor and seamy, so that the weight to be supported on the roof was problematic. It was necessary, therefore, to make provision for the support of more than 12 ft. of rock for a considerable part of the tunnel.

To meet these conditions, it was necessary to add from 50 to 100% to the strength of the roof. The steel roof-beams were already delivered. Several months would have been required to obtain additional structural steel. The conditions of the rock made it desirable, even imperative, that the permanent construction be placed without delay. The contractor had on hand a supply of rods ordered for other parts of the section. Furthermore, the rock had broken out, as described in the paper, above the neat line of excavation, so that the thickness of the roof could be increased without additional excavation. It was decided, therefore, to omit the jack-arches and increase the thickness of the concrete of the roof, so as to develop in effect a reinforced concrete slab.

The original plans showed an average thickness of concrete 3 in. above the top of the beams. This was increased to 12, 14, and 20 in. in various cases (making the depth of concrete 32, 34, and 40 in., respectively). Four 1-in. tension rods were added in each 5-ft. bay between adjacent bents. Assuming the roof to be a reinforced concrete slab, the reinforcing consisting of the rods and beams, the

neutral axis is found to be above the top of the beam. The web of the beam, therefore, assisted in resisting the vertical shear, but did not resist any part of the horizontal shear at the neutral axis. Six ¾-in. inclined shear rods were added, therefore, in each 5-ft. bay over each support. By this method of reinforcing, the supporting power of the roof was increased 50% for 32 in. thickness, 70% for 34 in. thickness, and 110% for 40 in. thickness of concrete. Mr. Griest.

It was also necessary to reinforce the center walls to carry a load even greater than the supporting power of the roof. (The rock being caught up near or over the center walls and the space filled later with hand-packed stone and rubble, made it probable that a greater loading would be carried on the walls than on the intervening roof beams.) The columns, therefore, were embedded in 12-in. and, in some cases, in 16-in. concrete walls, with eight 1-in. vertical rods in each 5-ft. bay. The load was then assumed to be distributed as in a reinforced concrete wall, over the steel and concrete.

JOHN H. MADDEN,* ASSOC. M. AM. SOC. C. E.—This work was of such magnitude, and the problems presented were so numerous, that the details would readily afford a field for several papers of the extent of that offered. Under such circumstances, the wisdom of illustrating the text profusely is apparent. The speaker believes that it may be of interest to review the development of the methods adopted for the tunneling operations and the experience during their execution, and, to that end, will devote his remarks in general to the work in progress for the first two years of these contracts, when he was in direct charge of the tunnel construction for the Public Service Commission. The author succeeded to that capacity in April, 1914. Mr. Madden.

Design.—For subways to carry intraurban traffic it is essential to provide ready access to stations, so as to offer the greatest convenience to the traveling public, and where the stations occur at frequent intervals, as is necessary in New York City, this demands the minimum depth below the street surface consistent with a feasible re-adjustment of the existing sub-surface structures which will be interfered with. In the work under discussion, this was complicated further by the location of the express stations of the lower level, at which points a practical connection had to be provided with the local or high-level service.

With these considerations in mind, the small rock cover in places, with its incidental construction difficulties in the tunneling, can be readily understood. Future building operations or other sub-surface reconstruction involving a disturbance of existing conditions, was an added factor in the problem of the design of the structure.

Excavation.—The general character of the material encountered in the excavation has been sufficiently described, except that in many places a considerable stratum of destroyed rock, overlying the ledge

* New York City.

Mr. Madden. rock, was penetrated. These deposits had been deprived of their cementing properties, and could usually be removed with a pick and shovel, though, when exposed in the face, they presented every appearance of ledge rock.

On starting the work, there was discussion as to adopting a bottom heading, but, in view of the many faults and seams common to rock of the character of Manhattan schist, it was feared that the use of this method might loosen the overlying material and complicate the subsequent removal of the upper section of the tunnel. With the top heading, support could be provided with the advance, before the ground had an opportunity to work and become heavy.

As shown in the paper, the finished two-track section was about 32 ft. wide, and the roof of the excavation was very flat. To permit the structure to be completed piecemeal, steel columns and longitudinal girders were substituted in the center wall for the original reinforced concrete design. By this means half of the structure could be built and blocked against lateral movement, and thereby avoid exposing the rock for the full section at one time.

Reference is made by the author to the completion of the upper level in advance of the work for the lower tunnels. It must be borne in mind that it is necessary to maintain progress in work of this character, and that the contractor must base his methods on the preliminary information as to the character of the material which will be encountered. Except where it is known that the tunnel roof will project above the rock outcrop into a sandy soil continuing to the upper level, and thereby induce a bleeding off below that level, with the probable disturbance of the intervening material, extending to either side and entailing settlement outside of the normal limits of the work, it would seem that some advantage can be claimed for this procedure. The completion of the upper level excavation removes the overhead load if poor ground is developed in the tunnel, or if the rock cover above the roof of the tunnel is very thin. The timbering of the upper level excavation may also act to localize any disturbance caused by the tunnel excavation, by retaining the side banks above and diminishing the possibility of an extensive outside settlement.

Where apprehension is felt as to settlement from this sequence of operations, it is not believed that underpinning abutting buildings is as effective for their protection against injury, as supporting their foundations on cribwork, as the latter admits of correction for settlement and, on the completion of the subway structure, such foundations can be extended to stable ground.

It is not intended, however, to question the wisdom of deferring the construction of the structure at the upper level in advance of the completion of the lower tunnel excavation where the latter is to be conducted through poor material. As stated by the author, where this

course was followed, voids were caused under the upper structure, and in some instances a cavity was developed between the two levels. An attempt was made to close the neck of this crater with small timber, sealing above it with concrete and packing the sides of the cavity with sand bags to prevent sloughing off. Grout was introduced under pressure from below, in order to consolidate the disturbed ground, but, as no great success was attained in preventing further development of the settlement, it was necessary ultimately to reconstruct the footings and track floor. Indifferent results were likewise obtained from efforts to compact the soft ground underlying the upper level so as to retain it in place during the subsequent excavation from the lower tunnel. Mr. Madden.

Blasting.—The diagrams and data in the paper supply full details of the blasting operations. Where buildings abut on tunnel work and are founded on the same rock strata to be excavated, some concussion is unavoidable, but the damage from this source was remarkably slight, under the circumstances.

In the vicinity of some of the portals the breakage of windows was quite extensive, because of the air vibrations following the blasting, and though several expedients were tried to break up the velocity of the discharge at the portals they met with no great success. The increase in the number of holes or the reduction in the charge of dynamite had no material effect in reducing the damage to the windows. The plate glass store-fronts were protected with small wooden blocks placed on each side of the glass over which wires were carried to a frame at the top and bottom of the window. This operated to confine the oscillations induced by the vibration, and proved very efficacious in preventing the breaking or cracking of the glass. It was not practical, however, to place this device on each of the great number of small house windows, and, when broken, these were promptly replaced.

Emphasis might well be laid on the use of the powerful searchlight which was mounted on a car in the tunnel and used for periodic inspection of all exposed rock. This readily disclosed any indications of the rock working, or spalls loosening, and suitable precautions could be taken as required. In some instances where the ground was treacherous, the searchlight was used to examine the face of the heading following the blasting and before any men were permitted to enter. Its use was an insurance factor that is worthy of adoption on work of this character.

Timbering.—Where timbering was necessary, the usual segmental type was used, and the design contemplated either the support of the overhead load where the ground was heavy or protection against injury through the dropping out of spalls or fragments where the rock was firm but blocky. When the soft water-bearing material was encountered at 74th Street, the contractor adopted the expedient (as

Mr. Madden. mentioned by the author) of driving long spikes in the sides of the caps, and these projected from their face and formed a bond; the space between the timber sets was then packed solid with concrete through which the grout pipes extended. This method proved so advantageous that it was used subsequently in other parts of the work to which it would apply.

By this method the timbering was not only greatly reinforced, but a very efficient and uniform support was provided for the roof between the sets. A seal was also obtained for the water draining off from above, and, where desirable, this could be collected and removed under control through grout pipes kept open for that purpose. In rock which is seamed and faulted, to the extent of that encountered in many places in this locality, it is important to minimize the time of the exposure of the face in the excavation, so as to reduce the tendency to work; and it is believed that concreting between sets as soon as practical after their erection offers an excellent solution of that problem. This is particularly applicable when the permanent lining cannot be completed coincident with the advance of the tunnel excavation.

As described in the paper, the work presented unusual problems in tunnel construction, and required from the contractors a severe tax on their experience and resourcefulness. Acknowledgment is due to The Bradley Contracting Company and P. McGovern and Company for the successful completion of their respective sections.

Mr. Jacobs. Robert H. Jacobs,* Assoc. M. Am. Soc. C. E.—This paper brings forcibly to the mind of the engineer the hazards necessarily incident to execution of work of this character. To those acquainted with such work, it is unnecessary to emphasize the fact that the process of driving tunnels, of the dimensions required for subway operation, to rock such as exists throughout Manhattan within the limits of city streets, it somewhat hazardous, even when carried on under the strictest and most competent supervision. This applies not only to the force employed, but also to some extent to the public. It is felt, therefore, that it is a matter for congratulation that in the total of 9 700 lin. ft. of tunnel work, including 3 100 lin. ft. of four-track tunnel, covered by this paper, there were no accidents affecting the public, the only injuries suffered being slight damages to buildings due to vibration and concussion, and, in the case of soft ground tunnels, a possible slight settlement in a few buildings.

Considering the close proximity of buildings (Lexington Avenue being only 75 ft. wide), the character of the material excavated, and the millions of people passing daily over the temporary supports in the case of the cut-and-cover work, the record of casualties for the whole subway work is an enviable one. It may be stated, however,

* New York City.

that the various processes of construction cannot be carried on with the same degree of safety as may be obtained in the operation of completed machines or structures. For example, if the same safeguards were thrown around the structural ironworker engaged on the erection of a skyscraper as are thrown around the passenger in the elevator of a completed building, the speaker is sure we would have no skyscrapers. In the same way, if the same safeguards were to be thrown around a tunnel excavator as around a subway passenger, there would be no subways. Mr. Jacobs.

It has seemed to the speaker that in undertaking this great work at the behest of our masters, the people, that the latter should be allowed to know in advance that there are certain necessary hazards incidental to such work, no matter how conscientiously and ably planned and executed. He is quite sure that such knowledge would in no wise deter them from their purpose to have these very necessary facilities provided. When, however, the public, through a lack of knowledge of the conditions under which work of this character is carried on, believes that it can and should be carried forward with absolute safety by the exercise of even ordinary care and skill, those in responsible relation to the work are subjected to the most severe criticism or worse, in the case of casualties.

This is being brought very forcibly to mind at this time by the recent failure of a portion of the erecting appliance of the Quebec Bridge. The general public is quite aware of the fact that the doctor is dealing with certain unknown elements in his work, and therefore does not hold him to strict accountability for the success of his treatment. It does not realize, however, that (although to a very much less extent) there are certain unknown elements which confront the engineer in the prosecution of work, which make it impossible for him to insure that it will be conducted with absolute safety, notwithstanding the fact that he is willing to accept full responsibility for the finished product. The lack of realization of this results in the engineer being held to an accountability which is unfair to the Profession. Here is an opportunity for educational work which can be accomplished by the engineer alone.

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PAPERS AND DISCUSSIONS

UNDERPINNING TRINITY VESTRY BUILDING FOR SUBWAY CONSTRUCTION

Discussion*

By James C. Meem, M. Am. Soc. C. E.

J. C. Meem,† M. Am. Soc. C. E. (by letter).‡—The author has covered the subject of this paper so ably and fully that very little remains to be said, except in reference to the elaboration of certain points which he has mentioned. Mr. Meem.

The sectional roof shield method of tunneling has been used on many important pieces of work, and is doubtless familiar to many, but the use of the "pilot-girder" in connection therewith is new. This was made of two lattice-girders, 4 ft. high, cross-tied and braced to form a continuous box-girder, the rear members, as stated, being carried forward and placed in position as required. The outer chords were made longer than the inner ones, in order to accommodate it to the curvature of the tunnel. The office of this girder was to carry the falsework over the bottom excavation between the heading and the completed section of the tunnel, and it proved to be a very satisfactory and efficient substitute for the arched timber method which had generally been used in connection with the sectional shield.

Owing to the shortness of the radius of curvature of this tunnel and the extreme accuracy with which the rings had to be set (the contractor was limited absolutely to a variation of not more than

* This discussion (of the paper by H. de B. Parsons, M. Am. Soc. C. E., published in August, 1916, *Proceedings*, and presented at the meeting of October 4th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Brooklyn, N. Y.

‡ Received by the Secretary, September 29th, 1916.

Mr. Meem. 2 in. at any point), it is doubtful whether any other method of tunneling could have been used so successfully and advantageously.

In the matter of the concrete key in the roof, which is shown in Fig. 16, very satisfactory results were obtained by filling beforehand these spaces in the cast-iron ring above the key. Heretofore, as far as the writer knows, no satisfactory method of filling these spaces after placing the key has been found, except by grouting. This key was placed by using a form with a movable bottom; on this the concrete was placed and then the whole mass was jacked into the roof space and maintained until it had set.

In the matter of the very limited dependence to be placed on skin friction resistance of piles, as noted by the author, the writer agrees very heartily. He believes that skin friction resistance is often mixed up with bearing resistance, and that, as a factor by itself, it has very little value, especially with smooth-bore piles. To assume a value of, for instance, 1 000 lb. per sq. ft. for skin friction resistance, as many engineers often do, is to assume that the pile withstands an external pressure of approximately 2 500 lb. per sq. ft. It is improbable, however, except in cases of very long piles in deep fluid strata, that piles are ever subjected to a pressure of more than a few pounds per square foot, and if this is true, skin friction resistance, of course, can be only a fraction of this pressure, so that, as stated, it may be neglected in nearly all cases. The pile, undoubtedly, derives its real support from the so-called "bulb of pressure" at its base.

MEMOIRS OF DECEASED MEMBERS.

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

EDWARD CANFIELD, M. Am. Soc. C. E.*

DIED AUGUST 18TH, 1916.

Edward Canfield, son of Caleb Augustus and Sarah Withington Canfield, was born at Geneva, N. Y., on May 27th, 1848. He was graduated from Hobart College in 1869, receiving the degree of A. B., and, in 1874, the degree of A. M.

In 1869, Mr. Canfield began his professional career in the Engineering Corps of the Erie and Geneva Valley Railroad. From 1870 to 1872, he was Division Engineer of the Syracuse Northern Railroad; from 1872 to 1873, Division Engineer of the Pennsylvania Petroleum Railroad; from 1873 to 1874, Assistant Engineer, Atlantic and Great Western Railway; from 1875 to 1878, Division Engineer of the Syracuse, Geneva and Corning Railroad; from 1879 to 1881, Assistant Engineer of the New York, Lake Erie and Western Railroad; and from 1881 to 1882, Roadmaster of the Rochester Division of the New York, Lake Erie and Western Railroad. While in the latter position, he organized and carried out the work of changing the entire Rochester Division from broad to standard gauge in one day.

On November 9th, 1882, Mr. Canfield entered the service of the New York, Ontario and Western Railway Company, in which he continued to the close of his life, having been first appointed Superintendent of Construction of the line from Middletown to Cornwall, N. Y., and from there to Weehawken, N. J., the latter portion being now a part of the West Shore Railroad, which is leased to and operated by the New York Central Railroad Company. In 1884, on the completion of the construction work, he was appointed Superintendent of the Southern Division.

On December 1st, 1887, he was appointed Chief Engineer in charge of new construction, maintenance of way, and bridges and buildings. As Chief Engineer, he had charge of locating and constructing the branch from Cadosia, N. Y., to Scranton, Pa., which gave the New York, Ontario and Western Railway Company entrance into the anthracite coal regions of Pennsylvania. In 1895, he was appointed General Superintendent, having charge of all operation except traffic, which office he held at the time of his death.

Mr. Canfield served for some years on the Board of Directors of the Orange County Trust Company, was, at the time of his death, a

* Memoir prepared by J. H. Nuelle, Esq.

Trustee of the Middletown Savings Bank, and, at one time, a member of the Board of Education of Middletown, N. Y.

The Board of Directors of the New York, Ontario and Western Railway Company adopted the following minute at a meeting held September 12th, 1916:

"This Board records its deep sense of loss in the death of Edward Canfield, late General Superintendent, which occurred at his home in Middletown, New York, on August 18, 1916.

"Mr. Canfield entered the service in 1882 in the Engineering Department, later becoming Chief Engineer, and in 1895 General Superintendent.

"In all his long service he displayed intense loyalty to the Company and its interests; to his skill as an engineer is due in large part the continued progressive advance in the physical condition of the property, while through his good judgment and careful management a high degree of efficiency in operation has been attained.

"His fine character, marked ability, untiring industry, absolute devotion to duty, and unfailing justice in his relations with all in the service, gained for him the profound respect and regard of all who knew him.

"No better example could be found in railroad service than the record of his life work."

He was married on September 17th, 1874, to Jane Hastings, daughter of Major David H. Hastings, of the United States Army, who, with their sons, David H. Canfield, Captain Edward Canfield, U. S. A., and Richard W. Canfield, survives him.

Mr. Canfield was a member of the Sigma Phi Fraternity, and was elected a Member of the American Society of Civil Engineers on December 3d, 1879.

SLEDGE TATUM, M. Am. Soc. C. E.*

DIED JANUARY 18TH, 1916.

Sledge Tatum, the son of Seth and Sarah Elizabeth Tatum, was born on July 10th, 1870, at LaGrange, Ga. He received his education at the LaGrange High School and from private instructors.

He began his professional career in 1886 in the Engineering Department of the Macon and Birmingham Railroad, and, later, was engaged in surveying and engineering work in Fulton and Troup Counties, Georgia.

In 1894 he was elected a member of the Georgia Legislature to represent Troup County.

* Memoir prepared by Frank Sutton, M. Am. Soc. C. E.

In May, 1895, Mr. Tatum was appointed Surveyor in the United States Geological Survey, and spent several years surveying land lines in Indian Territory. In 1899, he was appointed Topographer, and carried on triangulation in various States. In 1903, he surveyed forest boundaries in Washington and Idaho, and the following year executed triangulation along the International Boundary.

On June 10th, 1905, he was transferred from the Department of the Interior for service with the Department of Engineering of the Isthmian Canal Commission. He began work in the Canal Zone as Instrumentman on the Chagres River surveys, and advanced rapidly through the different grades, at one time having charge of all the survey parties in the field, both on the Chagres River Division and the Canal Zone boundary. On November 1st, 1908, Mr. Tatum was made Superintendent of Construction and was employed on the building of the Gatun Dam under Gen. William L. Sibert, M. Am. Soc. C. E., Division Engineer. He had charge of the surveys, the excavation at the spillway, and the driving and filling of all trestles. He resigned on February 8th, 1909, to accept a transfer to the United States Geological Survey.

On his return to the Survey, Mr. Tatum was assigned to special investigations and, on June 1st, 1910, was appointed Geographer in charge of the Rocky Mountain Division, comprising North and South Dakota, Kansas, Nebraska, Oklahoma, Montana, Wyoming, Colorado, New Mexico, and Texas, with summer headquarters at Denver, Colo. His duties comprised the planning and supervision of all topographic mapping in this area.

On December 10th, 1915, he was appointed Acting Chief Geographer of the Topographic Branch of the United States Geological Survey, in which capacity he served until his death.

Mr. Tatum was one of those rare combinations of thorough ability, good judgment, and consideration of the rights of others, and his death was a great loss, both to his associates in the Survey, with whom he had served for twenty years, and to his wide circle of friends.

C. L. Carpenter, M. Am. Soc. C. E., Manager of the Central Aguirre Company, of Central Aguirre, Porto Rico, writes of Mr. Tatum as follows:

"I believe there was hardly a person on the Isthmus during the time he was there who was so universally respected and liked by the people to whom he reported and by the people who reported to him, and I can hardly think of a person on the Isthmus to whom this would apply so well during the four years that I was connected with the Panama Canal. He certainly was a very loyal employee of the Isthmian Canal Commission and a very loyal friend. He was an extremely good judge of human nature and a good executive, and he did a great deal to help in training many young men while he was on the Isthmus.

"I know very few men who had all Mr. Tatum's good qualities, and it is certainly a pity that he should be called away so soon."

Mr. Tatum was a member of the Washington Society of Engineers and of the Cosmos Club of Washington. He also belonged to a Mississippi Commandery of Knights Templar.

He was married on May 5th, 1909, to Miss Sarah Richardson, of Huntsville, Ala., a daughter of Representative William Richardson and Elizabeth Benagh Rucker Richardson, and is survived by his wife.

Mr. Tatum was elected a Member of the American Society of Civil Engineers on January 4th, 1910.

STANLEY HASTINGS McMULLEN, Assoc. M. Am. Soc. C. E.*

Died July 12th, 1916.

Stanley Hastings McMullen, the third son of the late H. D. McMullen, was born at Aurora, Ind., on June 4th, 1872. He received his early education in the public schools of his home town, leaving the High School to enter the United States Naval Academy at Annapolis, Md., in May, 1893. He was obliged, on account of ill health, to leave the Naval Academy during his third year, and in September, 1895, he entered Purdue University where he took the course in Civil Engineering.

In May, 1899, Mr. McMullen entered the employ of the Illinois Central Railroad Company, as Track Apprentice. He remained with this Company until September, 1903, having attained the position of Resident Engineer in charge of construction. He was obliged to go West on account of his health and from September, 1904, to January, 1905, was engaged with the State Engineer of Colorado on the Colorado-Kansas Irrigation suit then before the Courts. On his return East he served as Division Engineer on 14 miles of construction for the Indianapolis and Louisville Traction Line, from April to December, 1906.

In January, 1907, Mr. McMullen went to El Paso, Tex., where he was engaged in private surveying until March of that year, when he was appointed City Engineer of Aurora, Ind. He held that position until October, 1907, during which time he planned the sewer system for that city and many street improvements.

Mr. McMullen then returned to Colorado and served as Assistant Engineer with the Denver Reservoir and Irrigation Company until January, 1908, when he returned to Anderson, Ind., to engage in the private practice of engineering.

* Memoir prepared by the Secretary from information on file at the Society House.

In September, 1913, he accepted a position as Assistant City Engineer and Draftsman at El Paso, Tex., which he held until April, 1915. Mr. McMullen afterward devoted his time to private practice in and around El Paso, and also at Lake City, Fla., until May, 1916, when he returned to Jeffersonville, Ind., fully intending within a short time to return to Orlando, Fla., where he had accepted a position. His health had been failing for some time and at the urgent request of his family he entered Christ Hospital, at Cincinnati, Ohio, where he died after an operation undertaken in a last effort to save his life.

In 1901 he was married to Miss Laura Frank, of Jeffersonville, Ind., who, with his three brothers, survives him.

Mr. McMullen was regarded as an engineer of exceptional ability and his work was always highly commended by his superiors. Owing to the fact that he was obliged, on account of his health, to live and work in many different parts of the country, his experience covered almost every phase of engineering work. He was a man of indomitable will power and of strong convictions, never hesitating to stand up for that which he deemed to be right or to oppose that which he considered wrong. He was a loyal and devoted member of the Methodist Episcopal Church which he had joined in his youth, and he will be greatly missed by his family, his friends, and associates.

Mr. McMullen was a member of the Indiana Engineering Society, and was elected an Associate Member of the American Society of Civil Engineers on November 3d, 1915.

JAMES MADISON WARNER, Assoc. M. Am. Soc. C. E.*

Died March 5th, 1916.

James Madison Warner, a son of the late William H. Warner, was born at Syracuse, N. Y., on August 4th, 1882. He was educated in the public schools of that city, and was graduated from the High School. In 1902, he entered the University of Illinois from which he was graduated in June, 1908, with the degree of B. S. in Civil Engineering.

Prior to entering college and during his summer vacations, Mr. Warner had been employed by the Chicago and Western Indiana Railroad Company as Chainman, Rodman, and Instrumentman on the work of track elevation into Chicago, Ill.

In 1908, he accepted a position as Instrumentman with the Grand Trunk Pacific Railroad Company, in connection with the grading and alignment of about 30 miles of track from Winnipeg, Man., west, and in 1909, he was engaged in the same capacity on track revision and

* Memoir prepared by the Secretary from information on file at the Society House.

grade alignment for the Chicago and Northwestern Railroad Company, at La Crosse, Wis.

Later in the same year, Mr. Warner went to Oralo, Tex., as Resident Engineer on 17 miles of construction on the Pecos and Northern Texas Railroad, a branch of the Santa Fé System. On the completion of this work in 1910, he was transferred to Sweetwater, Tex., where he had charge of the construction of 13 miles of heavy construction, large yards, a 600-ft. dam, etc.

In 1912, he abandoned railroad engineering and returned to Syracuse, N. Y., as Chief Engineer of the Onondaga Litholite Company, of which his brother, Mr. Henry P. Warner, is President. In addition to his duties as Chief Engineer, Mr. Warner became prominently identified with the general management of the business until March, 1915, when he was stricken with appendicitis. An operation followed, but complications developed which caused his death on March 5th, 1916, at the Syracuse Hospital for Women and Children.

While at college Mr. Warner had been prominent in student affairs, and was regarded as one of the most popular members of the undergraduate body. In his professional and business career, he had developed those qualities which insure success, and, despite his comparative youth, he had already won for himself a leading place in the industrial activities of Syracuse. His manly qualities of mind and heart had won for him many friends, and his death was a severe loss to them and to his family. Mr. Warner is survived by two brothers, Mr. Henry P. Warner, of Syracuse, N. Y., and Mr. Robert K. Warner, of Ouray, Colo., and by two sisters, Mrs. Henry K. Chadwick and Mrs. George A. Hanford, of Syracuse, N. Y.

He was a member of the Delta Tau Delta Fraternity, University of Illinois Chapter, the Citizens, Onondago Golf and Country, and the University Clubs, of Syracuse, N. Y., and Champaign Lodge, B. P. O. E.

Mr. Warner was elected a Junior of the American Society of Civil Engineers on April 6th, 1909, and an Associate Member on December 3d, 1913.

PAPERS IN THIS NUMBER

"THE YALE BOWL." CHARLES A. FERRY. (To be presented Nov. 15th, 1916.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 9

AMERICAN
SOCIETY OF
CIVIL
ENGINEERS
FOUNDED
1852

November, 1916

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLII—No. 9

NOVEMBER, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1916

* Director Virgil G. Bogue died October 14th, 1916.

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

SOCIETY AFFAIRS

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MINUTES OF MEETINGS

OF THE SOCIETY

October 18th, 1916.—The meeting was called to order at 8.30 P. M.; Director Arthur S. Tuttle in the chair; Chas. Warren Hunt, Secretary; and present, also, 114 members and 12 guests.

A paper by J. B. Lippincott, M. Am. Soc. C. E., entitled "A Method of Determining a Reasonable Service Rate for Municipally Owned Public Utilities", was presented by the Secretary and discussed by Messrs. T. Kennard Thomson, W. B. Yereance, and J. S. Branne.

The Secretary described the condition of the work of preparing the United Engineering Building for occupation by the Society, and matters in connection therewith were discussed informally by several members.

The Secretary announced the election of the following candidates on October 10th, 1916:

As Members

Curtis Marion Canady, Ambridge, Pa.
William Carey Coffin, Pittsburgh, Pa.
Charles James Crowley, New York City
Frederic Leslie Dudley, Ambridge, Pa.
Hugh Robert Edwards, San Francisco, Cal.
Frederick Arthur Gaby, Toronto, Ont., Canada
Winfred Dean Gerber, Chicago, Ill.
Ralph Dickinson Goodrich, Ypsilanti, Mich.
Nicholas Snowden Hill, Jr., New York City
Robert Wentworth Macintyre, Victoria, B. C., Canada
William Gouverneur Ramsay, Wilmington, Del.
Carl William Simpson, Norfolk, Va.
George Francis Sparhawk, Beaver, Pa.
Charles Albert Loring Wright, Springfield, Mass.

As Associate Members

Edward Morris Burd, Jackson, Mich.
James Cerny, Chicago, Ill.
Stanley Demalayne Cowden, San Luis Obispo, Cal.
Norman George Degnon, New York City
Frank Belasco deLara, Batavia, Java
Otto Elis Eckert, Saginaw, Mich.
James Harry Elder, Ambridge, Pa.
Leon Fleischmann, New York City
Norman Foster, Darby, Pa.
Daniel Edmund Gelwix, Springfield, Mo.
Theodore Gilman Griggs, Chatham, N. J.
Claude Irving Grimm, Cincinnati, Ohio
Samuel Alexander Hart, Manteca, Cal.
Estill Samuel Heyser, Dallas, Tex.
Grant Huntley, Schenectady, N. Y.
Elmer Acred Jacob, Lynndyl, Utah
Tobias Dillon Kilkenny, Vallejo, Cal.
Elmour Fitch Kirtland, Beaver, Pa.
Julius Lasker, Washington, D. C.
Rollin Fay MacDowell, Cleveland, Ohio
George Everett McNayr, Hanover Center, Mass.
Prentice Burdette Merwin, Quebec, Que., Canada
Bradley Revere Metcalf, Sherman, Cal.
Bennett Taylor Mial, Philadelphia, Pa.
Daniel Chambers Miller, College Station, Tex.

Earl Bliss Morgan, Worcester, Mass.
Frank Amende Muth, New Orleans, La.
Allen Eugene Nichols, Chicago, Ill.
Ray Rolph Palmer, Denver, Colo.
James Roy Pennell, Fort Bliss, Tex.
John James Garfield Pitney, Ambridge, Pa.
Steuart Purcell, Baltimore, Md.
Edward John Ruff, Sewickley, Pa.
David McDougald Shearer, Vicksburg, Miss.
Joseph Warder Small, Jr., Ambridge, Pa.
William Tyler Snodgrass, Washington, D. C.
Fred Tarrant, Springfield, Ill.
David Ogle Thomas, Belleville, Ill.
Edward Boyington Tourtellot, Elkader, Iowa
William Somers Wicker, East Liverpool, Ohio

As Associate

Harold Hansard Robertson, Pittsburgh, Pa.

As Juniors

James Hyde Forbes, San Francisco, Cal.
Walter Berton Grigsby, Youngstown, Ohio
Herman Dietrich Gunther, New York City
William Louis Havens, Ithaca, N. Y.
Attilio Felix Lipari, New York City
Richard Jeter Palmer, Jr., Norfolk, Va.
Harlowe McVicker Stafford, Buck Meadows, Cal.
Albert Wylford Swartz, Everett, Wash.
Henry Frieze Vaughan, Detroit, Mich.
Philip Joseph Walsh, Charleston, W. Va.
Albert Ellery Wardwell, Detroit, Mich.

The Secretary announced the transfer of the following candidates on October 10th, 1916:

From Associate Member to Member

Max Lee Cunningham, Oklahoma, Okla.
William Peyton Day, San Francisco, Cal.
Jacques Andre Fouilhoux, Portland, Ore.
Laurence Timmerman Gaylord, New York City
Joseph Goodman, New York City
Paul McGeehan, Kansas City, Mo.
Harold Tapley Pease, Deer Park, Wash.
Benson Bulkeley Priest, New York City
Grover Cleveland Pruett, Miles City, Mont.
Avalon Graves Robertson, Bocas del Toro, Panama

John Truesdale Stewart, St. Paul, Minn.
William Wolcott Tefft, Jackson, Mich.
Andrew Perry Wenzell, Detroit, Mich.
Judson Ray West, Seattle, Wash.
Robert Culin White, Little Rock, Ark.
Alfred Marshall Wyman, Long Island City, N. Y.

From Junior to Associate Member

Frank Stork Altman, Atchison, Kans.
Frank Louis Beal, Stamps, Ark.
William Arthur Burton, Mt. Pleasant, Tex.
Frank Dominic Cefalu, Burrwood, La.
Herbert Bismarck Foster, Berkeley, Cal.
Henry Charles Frisbie, Cornell, Wis.
Leonard Louis Hohl, Sausalito, Cal.
Bennett Kaminsky, Indianapolis, Ind.
Harootun Hovhannes Khachadoorian, Halifax, N. S., Canada
John Aspin Kienle, New York City
William Morton Kinney, Chicago, Ill.
Joseph Mastella Le Grand, Copper Cliff, Ont., Canada
Robert Aldridge Nowlin, Elkhorn, W. Va.
Stephen Eugene Page, Dallas, Tex.
Karl Lewis Ponzer, Sheridan, Ark.
Ervin Beecher Stevenson, Albany, N. Y.
Walter Gottfrid Stromquist, Cincinnati, Ohio
Adolph Teichert, Jr., Sacramento, Cal.
Franklin Thomas, Pasadena, Cal.
Allan Littell Trimpi, East Orange, N. J.
Roy Elsen Ward, Pittsburgh, Pa.

The Secretary announced the following deaths:

Virgil Gay Bogue (*Director*), of New York City, elected Member, September 15th, 1869; died October 14th, 1916.

Frank Edson Shedd, of Boston, Mass., elected Member, February 6th, 1907; died September 23d, 1916.

Augustus Waterous Agnew, of Victoria, B. C., Canada, elected Associate Member, July 2d, 1913; died September 17th, 1916.

Lester Lyman Coleman, of Maricopa, Cal., elected Junior, May 31st, 1910; Associate Member, April 1st, 1914; died August 11th, 1916.

Adjourned.

November 1st, 1916.—The meeting was called to order at 8.30 P. M.; Vice-President Alfred Craven in the chair; Chas. Warren Hunt, Secretary; and present, also, 142 members and 14 guests.

The minutes of the meetings of September 20th and October 4th, 1916, were approved as printed in *Proceedings* for October, 1916.

A paper by F. H. Peters, Assoc. M. Am. Soc. C. E., entitled "A Complete Method for the Classification of Irrigable Lands", was presented by the Secretary.

An informal discussion on the subject of "City Planning" was opened by N. P. Lewis, M. Am. Soc. C. E., and illustrated with lantern slides. The subject was discussed by Messrs. T. Kennard Thomson, W. F. Reeves, E. J. Mehren, Robert Ridgway, Hugh A. Kelly, and W. J. Boucher.

The Secretary announced the following deaths:

John Waldo Ellis, of Woonsocket, R. I., elected Member, July 3d, 1895; died October 29th, 1916.

Theodore Newel Ely, of Bryn Mawr, Pa., elected Member, March 2d, 1881; died October 28th, 1916.

Charles Wilcox Hotchkiss, of New York City, elected Member, January 5th, 1898; died October, 1916.

Leonard W. Rundlett, of St. Paul, Minn., elected Member, September 5th, 1883; died October 15th, 1916.

Adjourned.

OF THE BOARD OF DIRECTION

(Abstract)

October 10th, 1916.—The Board met at 10.05 A. M.; President Herschel in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Bontecou, Bush, Coleman, Cooley, Crocker, Davies, Endicott, Fuller, Hawley, Humphreys, Keefer, Khuen, McDonald, Marx, Montfort, Randolph, and Tuttle.

The appointment of Messrs. George A. Harwood, J. V. Davies, A. D. Flinn, Lewis D. Rights, and Chas. Warren Hunt, as representatives of this Society on the Library Board of the United Engineering Society was announced.

The receipt of $2 500 from the Cambria Steel Company, to be applied to the expenses of the Joint Special Committee of this Society and of the American Railway Engineering Association on Stresses in Railroad Track, was announced. Also that previously $2 500 had been received from the Bethlehem Steel Company for this same purpose.

A new form of application for admission to the Society was adopted.

A Report of a Committee on the adoption of a regular sequence for the holding of the Annual Conventions of the Society in the several Districts in turn, was received, and its recommendations were adopted.*

The Report of the Nominating Committee was presented; also a letter from the nominee for the office of President in which he declined the nomination.

George H. Pegram, M. Am. Soc. C. E., was selected (in accordance with Article VII, Section 3, of the Constitution), by the unanimous

* See page 699 for details of the plan adopted.

vote of the nineteen members of the Board present, to complete the list forwarded by the Nominating Committee.

A report was received from the Secretary as to the present condition of all matters relating to the movement of Society Headquarters, and authority was given to the representatives of this Society on the United Engineering Society Board to arrange to take over, when ready, the entire new fifteenth floor and one-half of the new sixteenth floor of the Thirty-ninth Street Building for the use of this Society.

The officers of the Society were authorized to take the necessary steps to mortgage the property of the Society in order to provide the necessary funds for the enlargement of the Building on Thirty-ninth Street.

The appointment by the President of Gen. William H. Bixby, M. Am. Soc. C. E., to represent this Society in a conference with a Committee of the National Academy of Sciences was announced.

Messrs. G. J. Fiebeger, William Cain, and W. K. Barnard, were appointed a Committee to Recommend the Award of Prizes.

President Herschel was authorized to appoint a Committee of three, of which he shall be Chairman, to represent this Society at any conference in Washington on Water Power Development.

The Constitution of the Detroit Association of Members, was approved.

Special meetings of the Society were authorized for the morning and afternoon of Friday, January 19th, 1917, for the purpose of discussing the forthcoming Report of the Special Committee on Materials for Road Construction.

The President was authorized to appoint three representatives from this Society to meet with a similar representation from the Electrical, Mechanical, Mining, and Testing Materials Societies, to consider and report back to their respective governing bodies, on Ways and Means of Bringing about Co-operation in American Engineering Standards.

President Clemens Herschel was appointed a member of the John Fritz Medal Board of Award to fill the vacancy which will be caused by the expiration of the term of Past-President John A. Ockerson on January 19th, 1917.

The resignations of 1 Member and 2 Associate Members were accepted.

Ballots for Membership were canvassed, resulting in the election of 14 Members, 40 Associate Members, 1 Associate, and 11 Juniors, and the transfer of 21 Juniors to the grade of Associate Member.

Sixteen Associate Members were transferred to the grade of Member.

Applications were considered and other routine business transacted.

Adjourned.

SOCIETY ITEMS OF INTEREST

Sequence of Annual Conventions

The Board of Direction, at its meeting of October 10th, 1916, considered and adopted a "method by which the Annual Convention would move automatically from one district to another in such sequence as would insure that all parts of the country are brought into closer touch with the Society's work".

An analysis was made of the record of the places where Conventions have been held in the past, in order to decide on a proper rotation of Districts for future Conventions. It was also noted that in ten of the Districts from one to three Local Associations have been formed.

It is assumed that the Local Association, or Associations, in each District, acting in conjunction with the membership in that District, and with its representative on the Board of Direction, will have no difficulty in selecting a place within the limits of that District.

This will insure continued active interest in the Society on the part of the membership in each District.

The rotation of Districts in which Conventions shall be held was adopted as follows:

In	1917	District	No.	7
"	1918	"	"	11
"	1919	"	"	2
"	1920	"	"	12
"	1921	"	"	5
"	1922	"	"	10
"	1923	"	"	6
"	1924	"	"	9
"	1925	"	"	3
"	1926	"	"	8
"	1927	"	"	13
"	1928	"	"	4

A suggestion that a second meeting be held, outside of New York City, was also considered.

The Board is of the opinion that, if such a meeting could be given a distinctly technical character, and be designated as one of the Business Meetings provided for by Art. VIII, Sec. 3, of the Constitution, it would result in centering activity in each District at least once in 6 years, instead of 12, as would otherwise be the case; that to carry out such a plan would not have a prejudicial effect on the attendance at the Convention; and, if the preparation of an additional programme for social and other activities were not regarded as in any way obligatory, no additional burden would be placed on the membership in any District.

The Board, therefore, decided that the option of assuming responsibility for a second meeting in any year shall be offered to each District in turn, with the understanding that it can be accepted or declined.

The rotation adopted is in the same order as for the Conventions, but beginning with District No. 5.

For these optional semi-yearly meetings, the order, therefore, is:

In	1917	District	No.	5
"	1918	"	"	10
"	1919	"	"	6
"	1920	"	"	9
"	1921	"	"	3
"	1922	"	"	8
"	1923	"	"	13
"	1924	"	"	4
"	1925	"	"	7
"	1926	"	"	11
"	1927	"	"	2
"	1928	"	"	12

It is expected that, in arranging for these two meetings outside of New York City, the time shall be selected for spring and fall, with reference, in each case, to the climatic conditions of the place selected.

Following this action of the Board of Direction, the Annual Convention of 1917 will be held in District No. 7, comprising Michigan, Wisconsin, Minnesota, Iowa, Ontario, and Manitoba.

The second meeting, if desired by District No. 5, will be held in that District, which comprises Virginia, North and South Carolina, Georgia, Florida, and the District of Columbia.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

December 6th, 1916.—8.30 P. M.—A regular business meeting will be held. No paper has been set down for presentation at this meeting, but the resident members will be notified regarding the subject for discussion before that date.

December 20th, 1916.—8.30 P. M.—At this meeting a paper by L. P. Jerrard, Jun. Am. Soc. C. E., entitled "The Valuation of Land", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING

The Sixty-fourth Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 17th and 18th, 1917. The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, Officers for the ensuing year elected, members of the Nominating Committee appointed, Reports of Special Committees presented for discussion, and other business transacted.

SPECIAL MEETINGS

Meetings for the discussion of the Progress Report of the Special Committee on Materials for Road Construction, will be held at 10 A. M. and 2 P. M. on Friday, January 19th, 1917 (the day following the close of the Annual Meeting of the Society).

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generaly known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings.*

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions.*

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings.*

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

President, H. L. Haehl; Secretary, E. T. Thurston, 57 Post Street, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the

Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

Colorado Association, Organized 1908.

President, Thomas W. Jaycox; Secretary-Treasurer, L. R. Hinman, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

Atlanta Association, Organized 1912.

President, Paul H. Norcross; Secretary-Treasurer, Thomas P. Branch, Georgia School of Technology, Atlanta, Ga.

The Association holds its meetings at the University Club, Atlanta, Ga. Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

Baltimore Association, Organized 1914.

President, H. D. Bush; Secretary-Treasurer, Charles J. Tilden, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

President, Robert Hoffmann; Secretary-Treasurer, George H. Tinker, Hickox Building, Cleveland, Ohio.

Detroit Association, Organized 1916.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

President, A. P. Davis; Secretary-Treasurer, John C. Hoyt, U. S. Geological Survey, Washington, D. C.

Illinois Association, Organized 1916.

President, Onward Bates; Secretary-Treasurer, E. N. Layfield, 4251 Vincennes Avenue, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the

Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

President, W. B. Gregory; Secretary, Charles W. Okey, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

(Abstract of Minutes of Meetings)

July 22d, 1916.—The meeting was called to order at 8 P. M., at The Cabildo; President W. B. Gregory in the chair; Charles W. Okey, Secretary; and present, also, 8 members.

The resignation of Mr. E. H. Coleman as Secretary was read, and, on motion, duly seconded, was accepted.

Mr. Charles W. Okey was nominated as Secretary and, no other nominations being made, was declared elected.

On motion, duly seconded, it was decided to appoint a committee to select from the *Proceedings* of the Society, or from other publications, some paper for discussion at the following meeting and at future meetings. The Secretary was instructed to confer with the Secretary of the Local Chapter of the American Society of Mechanical Engineers, with reference to selecting a paper for discussion at the joint meeting of the Associations to be held on October 2d, 1916.

The President made a brief report of the Annual Convention of the Society held at Pittsburgh, Pa., on June 27th-30th, 1916.

On motion, duly seconded, it was decided to pay $100, on October 1st, 1916, into the Library Fund of the Louisiana Engineering Society, the vote standing 19 for and 3 against the donation.

Adjourned.

October 2d, 1916.—The joint meeting of the Association and the Local Chapter of the American Society of Mechanical Engineers, was called to order at The Cabildo; W. B. Gregory, President of both organizations, in the chair; Messrs. Charles W. Okey and H. L. Hutson, Secretaries; and present, also, members and guests.

Owing to the fact that this was a joint meeting, business matters were dispensed with, and discussion on a paper by Mr. G. C. Noble, of San Francisco, Cal., entitled "A Large Reclamation Pumping Plant", which was published in the *Journal* of the American Society of Mechanical Engineers for May, 1916, was opened by Mr. Gregory. The subject was further discussed by Messrs. H. L. Hutson, A. M. Shaw, A. T. Dusenbury, and Charles W. Okey.

Adjourned.

Northwestern Association, Organized 1914.

President, W. L. Darling; Secretary, Ralph D. Thomas, Minneapolis, Minn.

Philadelphia Association, Organized 1913.

President, Samuel T. Wagner; Secretary, C. W. Thorn, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

(Abstract of Minutes of Meeting)

October 2d, 1916.—The Annual Meeting was called to order at 8.15 P. M., at the Engineers' Club of Philadelphia; President Edward B. Temple in the chair; W. L. Stevenson, Secretary; and present, also, 50 members and guests.

Messrs. Percival M. Sax, James F. Cullen, and Charles Frommer were appointed Tellers to canvass the ballots for officers.

The Secretary read the following resolution adopted by the Board of Direction:

"The Board of Direction recommends that Article II, Section 1, of the Constitution, be amended to read:

" 'Section 1. The membership of this Association shall be restricted to Members (Corporate Members, Associates and Juniors) of the American Society of Civil Engineers resident in the Fourth District, exclusive of the State of Maryland. Each member of the Society resident within the limits above defined shall become a member of this Association by so declaring himself in writing to the Secretary.'

"The Board further recommends that this amendment be submitted to the Board of Direction of the Society and, if approved, that it be submitted to the Association for adoption by letter ballot."

On motion, duly seconded, the meeting approved the resolution of the Board of Direction.

The President announced that Col. George A. Zinn, Corps of Engrs., U. S. A., having been ordered to report for active field duty on the Mexican border, had tendered his resignation as a member and as a Director of the Association. He stated that the Board of Direction, having accepted with deep regret Col. Zinn's resignation as a Director to take effect on October 2d, 1916, had requested him to retain his membership in the Association.

President Temple also announced that Mr. W. L. Stevenson had been elected by the Board to fill Col. Zinn's unexpired term as Director until 1917.

F. Herbert Snow, M. Am. Soc. C. E., presented a paper entitled "Engineering—State, Municipal, and Corporate—Involved in the Administration of the Pennsylvania Public Service Company Law", and the subject was discussed by Messrs. Ledoux, Fisher, Marburg, Webster, and Wagner.

On motion, duly seconded, a vote of thanks was tendered Mr. Snow.

The Tellers appointed to canvass the ballots for officers, reported the following elections: President, Samuel T. Wagner; Vice-President, Edgar Marburg; Directors, Harrison Souder, Frederick E. Schall; and Secretary, C. W. Thorn.

Mr. Wagner was installed as President and made a short address.

Adjourned.

Portland, Ore., Association, Organized 1913.

President, J. P. Newell; Secretary, J. A. Currey, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1914.

President, J. A. Ockerson; Secretary-Treasurer, Gurdon G. Black, 34 East Grand Avenue, St. Louis, Mo.

The meetings of the Association are held at the Engineers' Club Auditorium. The Annual Meeting is held on the fourth Monday in November. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

San Diego Association, Organized 1915.

President, N. B. Kellogg; Secretary-Treasurer, J. R. Comly, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

President, A. O. Powell; Secretary-Treasurer, Carl H. Reeves, 444 Henry Building, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Arctic Club.

(Abstract of Minutes of Meeting)

September 25th, 1916.—The meeting was called to order at 12.15 P. M., at The Arctic Club; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 24 members and guests.

The minutes of the meeting of August 28th, 1916, were read and approved.

A letter from the Secretary of the National Conference on City Planning was read, asking for recommendations as to the place for the next meeting and whether or not a representative from the Association would be sent to that meeting. On motion, duly seconded, Kansas City was endorsed as the best location for the next meeting of the Conference and the Secretary was instructed to advise the Secretary of the Conference that delegates to the meeting would be appointed if available.

The report of the Water Code Conference Committee was presented with recommendation in regard to certain changes in the bill as drawn. The report was discussed by Messrs. Gray, Howes, Lundgren, Fuller, and Powell, and on motion, duly seconded, a copy was ordered sent to each member of the Association and the report presented for discussion at the next meeting.

Adjourned.

Southern California Association, Organized 1914.

President, William Mulholland; Secretary, W. K. Barnard, 1105 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

(Abstract of Minutes of Meeting)

October 11th, 1916.—The meeting was called to order at the Hotel Clark; Vice-President Harry Hawgood in the chair; W. K. Barnard, Secretary; and present, also, 35 members and guests.

The minutes of the meeting of July 12th, 1916, were read and approved, and reports of regular and special committees presented.

The subject of suggestions to be made by members of the Association relative to a member of the Nominating Committee of the Society from this District, was discussed, and, on motion, duly seconded, it was decided that the Association select a candidate for this appointment, and make such endeavors toward his election as may be proper.

The names of Messrs. Louis C. Hill and F. H. Olmsted were presented, and, after further discussion, on motion, duly seconded, the Secretary was instructed to send cards to all members of the Association notifying them that it was the sense of this meeting that Mr. Hill should be selected for this appointment on the Nominating Committee of the Society from this District.

On motion, duly seconded, the suggestion made in the report of the Joint Committee on Technical Societies, that members of the Association join with members of other local technical organizations in weekly midday lunch, with a view to fostering a spirit of co-operation between the members of such organizations, was carried.

A letter from the Philadelphia Association was read relative to the publication of papers presented before the Southern California Association in the *Bulletin* of the Engineers' Club of Philadelphia, in the event that such papers are not to appear in the *Proceedings* of the Society.

Francis L. Sellew, M. Am. Soc. C. E., addressed the meeting on "The Control of the Colorado River". On motion, duly seconded, a vote of thanks was extended to Mr. Sellew for his interesting paper.

Philip Asfordby Beatty, M. Am. Soc. C. E., a guest of the Association, addressed the meeting on his experiences during an overland trip from New York by automobile.

Adjourned.

Spokane Association, Organized 1914.

President, E. G. Taber; Secretary, B. J. Garnett, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

(Abstract of Minutes of Meeting)

October 13th, 1916.—The meeting was called to order at the University Club; Vice-President Morton Macartney in the chair; B. J. Garnett, Secretary; and present, also, 5 members and guests.

The meeting was devoted to an informal discussion of the merits of the Commission form of government as applied to Counties, and its effect on the office of County Engineer.

Adjourned.

Texas Association, Organized 1913.

President, John B. Hawley; Secretary, J. F. Witts, Dallas, Tex.

Utah Association, Organized 1916.

President, E. C. La Rue; Secretary-Treasurer, H. S. Kleinschmidt, 306 Dooley Building, Salt Lake City, Utah.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Steel Columns and Struts

October 2d, 1916.—The meeting was called to order at 8 P. M., at the House of the Society. Present, George H. Pegram (Chairman), C. W. Hudson, Ralph Modjeski, George F. Swain, J. R. Worcester, and Lewis D. Rights (Secretary). Dr. G. R. Olshausen, Engineer-Physicist of the Bureau of Standards, and his Assistant, Professor Nelson, were also present.

The minutes of the meeting of June 23d, 1916, were approved as written.

For the Committee on Initial Sets, Dr. Olshausen reported that he had made a number of specimen tests, both in compression and tension, and he submitted some photostat prints of stress-strain diagrams. The Committee was continued.

On motion, the Chairman and Secretary were requested to plot the stress-strain diagram for the Progress Report, and to have the other stress-strain diagrams plotted for the use of the members of the Committee.

Considerable discussion was brought out on the subject of Safe Working Values, and the members of the Committee were requested to submit a referendum, in order that Mr. Worcester may write a final discussion on that subject. On motion, the question was continued until a later meeting, when the entire session is to be devoted to this one subject.

The Secretary submitted a preliminary draft of the Progress Report of the Committee, the general features of which were approved. Minor changes were suggested, and the Secretary was requested to rewrite the Report so that it could be passed on by the Committee at its next meeting.

On motion, the Committee adjourned to meet at the call of the Chairman.

Special Committee to Investigate Conditions of Employment of, and Compensation of, Civil Engineers

October 16th, 1916.—The meeting was called to order at the House of the Society at 10 A. M., and was continued in the afternoon at the

Engineers' Club. Present, Nelson P. Lewis (Chairman and Acting Secretary), John A. Bensel, S. L. F. Deyo, and C. F. Loweth.

It was agreed that the Committee should submit its Final Report at the Annual Meeting of the Society to be held on January 17th, 1917. A draft of the report, as prepared by the Chairman and mailed to the members of the Committee, was discussed in detail and amended in some particulars.

The Chairman was requested to revise further some of the paragraphs and mail the revised report to the members of the Committee.

The Committee adjourned subject to the call of the chair.

Special Committee on Materials for Road Construction

October 21st, 1916.—The meeting was called to order at 10.30 A. M., at the Society House. Present, Nelson P. Lewis (Chairman *pro tem.*), H. K. Bishop, A. W. Dean, Charles J. Tilden, A. H. Blanchard (Secretary), and Clemens Herschel, President, Am. Soc. C. E.

The minutes of the meeting of September 23d, 1916, were read and approved.

The Secretary read a communication from Charles Warren Hunt, Secretary of the Society, stating that the Board of Direction had granted the request of the Committee to hold Special Road Meetings of the Society on January 19th, 1917, for the purpose of affording opportunity for full discussion of the Committee's 1917 Report, and also that the Board had assented to the printing of 500 copies of that Report for distribution among non-members of the Society, in order to secure a thorough discussion.

On motion, duly seconded, the Final Reports of the Sub-Committees on Gravel Roads, Broken Stone Roads, Broken Stone Roads with Bituminous Surfaces, and Bituminous Macadam Pavements, with certain additions thereto, were adopted.

The Secretary read a communication from W. W. Crosby, Chairman of the Committee, containing comments relative to the Final Reports of the Sub-Committees mentioned previously.

On motion, the Committee adjourned to meet at 9 A. M. on November 4th, 1916.

Special Committee on Valuation of Public Utilities

43d to 48th meetings. Held at the House of the Society. October 23d-28th, 1916.

Forty-third meeting, October 23d, 1916.

First Session.—10 A. M. to 1 P. M.—The full Committee met. Present, Frederic P. Stearns (Chairman), Charles S. Churchill, William G. Raymond, Henry E. Riggs, Jonathan P. Snow, William J. Wilgus, and Leonard Metcalf (Secretary).

President Herschel, member of the Committee, *ex officio*, joined the Committee to note its method of working, and suggested the desirability of alluding to the unsettled character of certain phases of the valuation problem, in presenting its report to the Society.

It was moved that a "Preface" be prepared for the report, embodying the matters discussed. The morning was spent in discussing the Glossary and Chapters I and II of the report.

Second Session.—2.15 P. M. to 6.45 P. M.—The full Committee reconvened and spent the afternoon in discussing Chapter V on Reproduction Cost.

Third Session.—8 P. M. to 10 P. M.—Discussion of the Chapter on Reproduction Cost was resumed.

Forty-fourth meeting, October 24th, 1916.

First Session.—9 A. M. to 1 P. M.—Present, Messrs. Stearns, Churchill, Raymond, Riggs, Snow, and Metcalf. The morning was spent in further discussion of Chapter V on Reproduction Cost.

Second Session.—2 P. M. to 6 P. M.—Discussion of Chapter V on Reproduction Cost—including Treatment of Land Holdings—was concluded.

Third Session.—8 P. M. to 10.30 P. M.—Present, the entire Committee. The evening was spent in discussing Chapter VII on Development Expense.

Forty-fifth meeting, October 25th, 1916.

First Session.—9 A. M. to 1 P. M.—Present, the full Committee.

Voted: That the Glossary be transferred from the beginning to the end of the report.

Voted: That a brief "Summary of Conclusions" be prepared for insertion after the Table of Contents.

The morning was spent in discussion of Chapters VII and VIII on Development Expense and Going Value.

Second Session.—2 P. M. to 6.15 P. M.—Present, the full Committee. The discussion on Chapter VIII on Going Value was resumed, and that on Chapter VI, Depreciation, was taken up.

Third Session.—8 P. M. to 10.15 P. M.—Present, the full Committee. The evening was spent in discussing Chapter VIII on Going Value.

Forty-sixth meeting, October 26th, 1916.

First Session.—9 A. M. to 1 P. M.—Present, the full Committee.

Second Session.—2 P. M. to 5.15 P. M.—Present, the full Committee, except Mr. Wilgus.

Third Session.—8 P. M. to 10 P. M.—Present, the full Committee. The entire day was spent in discussion of Chapter VI on Depreciation.

Forty-seventh meeting, October 27th, 1916.

First Session.—9 A. M. to Noon.—Present, the entire Committee, except Mr. Wilgus. Discussion on Chapter V on Reproduction Cost resumed.

Second Session.—2 P. M. to 6 P. M.—Present, all members of the Committee, except Mr. Snow. The discussion on Chapter V on Reproduction Cost was concluded.

Voted: That the corrections agreed to in Committee, edited as necessary by the Secretary, be made in galley proof, and that thereafter revised galley proof be sent to all members of the Committee as soon as possible.

Voted: That after final correction has been made on the galley proof, the report may be printed without waiting for further suggestions from the Committee on the page proof, but that copies of the page proof be sent to the several members of the Committee when ready.

After conference with Secretary Hunt, it was

Agreed: That the report of the Committee should be printed in the December issue of *Proceedings*, and thereafter be open to written discussion by the members of the Society. Should the Appendices, I. Depreciation Tables; II. Some Examples of Expectation of Life of So-called Permanent Structures; III. Data upon Overhead Costs; not be ready for publication with the report in the December *Proceedings*, they will be printed in a later issue. Although they are of significance and convenience to the valuing engineer, they are not essential to the text of the report.

Third Session.—8 P. M. to 11 P. M.—Present, Messrs. Stearns, Churchill, Raymond, Wilgus, and Metcalf. The evening was spent in discussing the conditions which should govern the estimate of reproduction cost of a public utility property.

Forty-eighth meeting, October 28th, 1916.

First Session.—9 A. M. to 1 P. M.—Present, Messrs. Stearns, Churchill, Raymond, Riggs, and Metcalf. The morning was spent in final revision of Chapter VI on Depreciation.

Voted: That it is desirable that if the discussions of the Committee's report require a closing statement, such closing statement shall be made only if unanimous, and shall then come from the Committee, rather than from any member or different members thereof, to the end that the closure may have the weight of the Committee's viewpoint and serve as an amplification of the report itself.

The Committee adjourned at noon, leaving its Secretary to prepare, for the printer, the revision of galley proof discussed by the Committee.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18–1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From October 4th to November 1st, 1916)

DONATIONS*

RAILWAY ORGANIZATION AND MANAGEMENT.

By James Peabody. Cloth, 9 x 6 in., illus., 7 + 263 pp. Chicago, La Salle Extension University, 1916.

The object of this book, the preface states, is to summarize the organization and management of representative transportation companies of the United States, to illustrate the activities of the various departments of such companies, and to show their relation to one another in such manner as to make clear to student and layman, the system underlying the efficient conduct of the properties. The various departments, construction, operation, transportation, accounting, etc., etc., are taken up in order, and the work of each and the methods of performing such work are discussed, but as the book is one of a series dealing with interstate commerce and railway traffic, the activities of the traffic department are given more space than the others. A number of charts showing the relations of officials to each other, and for the reader's guidance through the complexities of organization, are also included. Clear and concise discussions of problems of all kinds to be considered by railroad men, such as government regulation, valuation, apprentices, pensions, reports, statistics, advertising, etc., etc., are also given, making this work, it is stated, an able introduction to the business of railroading. The Contents are: Introduction; Supervision; Engineering; Operation: The Operating Unit; Conducting Transportation; Operation Maintenance; Mechanical Department; Types of Organization; Traffic Department: Sources of Revenue; Examples of Freight Traffic Organization; Passenger Traffic; Auxiliary Departments; Accounting Department; Examples of Accounting Organizations; Miscellaneous Departments; Examples of Typical Organizations; Index.

HOW TO MAKE LOW-PRESSURE TRANSFORMERS.

By F. E. Austin. Third Edition, with Additions. Cloth, 7¼ x 4½ in., illus., 22 pp. Hanover, N. H., The Author, 1916. 40 cents.

This book, it is stated, contains instructions regarding the design, construction, and operation of small transformers for experimental purposes, such as operating low-pressure tungsten lamps, ringing bells, operating small direct-current series motors used with fans or small electric cars, sparking devices for gasolene engines, arclights, etc. As here presented, these instructions will enable any one, it is said, to build a small transformer, at a small cost, without the use of expensive tools or machinery, which may be connected with any house circuit where the pressure is 110 volts or less, and the frequency about 60 cycles, and which may be stepped down to a minimum of 8 volts. For a small device, the efficiency of these transformers is high, being more than 90% for an output of 100 watts. This edition, it is stated, has been greatly enlarged and contains a new and simple form of core construction, as well as descriptions of the construction of a small transformer without the use of discs for a core and the utilization of ordinary tin cans as transformer cores. The Contents are: Directions; Transformer; Regulation; Recapitulation; Special Core Construction; A Transformer for 220 Volts, 60 Cycles; Special Type of Construction; Using Old Tin Cans for Transformer Cores; Notes for Experimenters; Useful Applications of Low-Pressure Transformers; To Operate Spark Coils; Step-Up Transformers.

HANDBOOK OF ROCK EXCAVATION: METHOD AND COSTS.

By Halbert Powers Gillette, M. Am. Soc. C. E. Leather, 7½ x 5 in., illus., 17 + 825 pp. New York, Clark Book Company, Inc., 1916. $5.00.

The purpose of this book, the preface states, is to place before those interested in the economic handling of rock, in handbook size and style, detailed descriptions of tools and machines required for modern rock work, blasting operations, including chamber blasting, and various methods of excavating and transporting rock under different conditions, together with many examples and unit cost data relative to all such work. The book, it is said, contains the bulk of the material published previously by the author in his work on "Rock Excavation, Methods and Costs", but as the methods and machinery used in rock excavation have become highly specialized,

* Unless otherwise specified, books in this list have been donated by the publishers.

much that is new has been added to the subject-matter. It is the author's purpose, the preface states, to publish shortly two companion handbooks on "Earth Excavation" and "Tunnels and Shafts", respectively. The Chapter headings are: Rocks and Their Properties; Methods and Cost of Hand Drilling; Drill Bits: Shape, Sharpening and Tempering; Machine Drills and Their Use; Cost of Machine Drilling; Steam, Compressed Air and Other Power Plants; Cable Drills, Well Drills, Angles and Cost Data; Core Drills; Explosives; Charging and Firing; Methods of Blasting; Loading and Transporting Rock; Quarrying Dimension Stone; Open Cut Excavation in Rubble Quarries, Pits and Mines; Railroad Rock Excavation and Boulder Blasting; Canal Excavation; Trench Work; Subaqueous Rock Excavation; Index.

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It is stated in a secondary title that this book is a complete and reliable annual register of producers, manufacturers, dealers, and consumers connected with the industries mentioned in the title and with many others of interest to buyers and sellers. Products are listed, it is said, from the raw material to the finished article, together with the names of companies and firms handling such products from the producer to the consumer, and the volume is stated to be indispensable as a buyer's reference and for mailing purposes. There is an alphabetical list of contents which is followed by a classified list of industries also arranged alphabetically under which is given, sometimes by States and cities, the names and addresses of firms dealing in the various articles, followed by detailed matter, titles of identification, etc. There is also a list of trade names, brands, etc., and an alphabetical list of advertisers including the addresses of their domestic and foreign branches.

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DUDLEY, FREDERIC LESLIE. Engr., Bridge Drawing Room, Am. Bridge Co., Ambridge, Pa.		Oct. 10, 1916
EDWARDS, HUGH ROBERT. Chf. Engr., Hammon Eng. Co., 433 California St., San Francisco, Cal.		Oct. 10, 1916
GABY, FREDERICK ARTHUR. Chf. Engr., Hydro-Elec. Power Comm. of Ontario, 190 University Ave., Toronto, Ont., Canada		Oct. 10, 1916
GERBER, WINFRED DEAN. Cons. Engr. (W. S. Shields Co.), 1203 Hartford Bldg., Chicago, Ill.		Oct. 10, 1916
GOODMAN, JOSEPH. Asst. Engr., Dept. of Water Supply, Gas and Electricity, 605 West 142d St., New York City	Assoc. M. M.	June 6, 1906 Oct. 10, 1916
GOODRICH, RALPH DICKINSON. Mgr., Public Utilities, 211 North Huron St., Ypsilanti, Mich.		Oct. 10, 1916
HILL, NICHOLAS SNOWDEN, JR. Cons. Engr., 100 William St., New York City		Oct. 10, 1916
MCGEEHAN, PAUL. Senior Civ. Engr., Grade One, Interstate Commerce Comm., Kansas City, Mo.	Assoc. M. M.	July 10, 1907 Oct. 10, 1916
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PRUETT, GROVER CLEVELAND. City Engr., Box 161, Miles City, Mont.	Jun. Assoc. M. M.	Mar. 2, 1909 Feb. 6, 1912 Oct. 10, 1916
SIMPSON, CARL WILLIAM. 507 Terminal Bldg., Norfolk, Va.		Oct. 10, 1916
SPARKHAWK, GEORGE FRANCIS. Engr. in Chg., Drawing Room No. 4, Am. Bridge Co., Ambridge, Pa.		Oct. 10, 1916
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WYMAN, ALFRED MARSHALL. Asst. Div. Engr., Public Service Comm., Room 409, Queens Plaza Court Bldg., Long Island City, N. Y	Jun. Assoc. M. M.	Jan. 2, 1906 Mar. 2, 1909 Oct. 10, 1916

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ATWATER, HUNTINGTON CLARK. In Dept. of Designs, New York Public Service Comm., Tribune Bldg., New York City (Res., 9 Livingstone Ave., White Plains, N. Y.).

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JUNIORS

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Gons, Louis Richard. Care, Fred T. Ley & Co., Inc., Springfield, Mass.

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Hutchins, Roland Ellis. Care, Morgan Eng. Co., 610 Goodwyn Inst., Memphis, Tenn.

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Loida, Joseph Louis. 2112 Felix Ave., Memphis, Tenn.

Mills, Guy G. Div. Engr., Portland Cement Assoc., 1123 Hurt Bldg., Atlanta, Ga.

JUNIORS (*Continued*)

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OLSON, JOHN NATHANAEL. Care. Eng. Dept., G. C. & S. F. Ry., Galveston, Tex.
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WEBB, CHAUNCEY EARL. 524 Monroe St., Gary, Ind.

RESIGNATIONS

MEMBERS	Date of Resignation.
CHURCH, WILLIAM LEE	Oct. 10, 1916
ASSOCIATE MEMBERS	
BEACH, JAMES GEORGE	Oct. 10, 1916
GRISWOLD, HORACE SETH	Oct. 10, 1916

DEATHS

AGNEW, AUGUSTUS WATEROUS. Elected Associate Member, July 2d, 1913; died September 17th, 1916.
BOGUE, VIRGIL GAY. (*Director.*) Elected Member, September 15th, 1869; died October 14th, 1916.
COLEMAN, LESTER LYMAN. Elected Junior, May 31st, 1910; Associate Member, April 1st, 1914; died August 11th, 1916.
ELY, THEODORE NEWEL. Elected Member, March 2d, 1881; died October 28th, 1916.
HOTCHKISS, CHARLES WILCOX. Elected Member, January 5th, 1898; died October 29th, 1916.
RUNDLETT, LEONARD W. Elected Member, September 5th, 1883: died October 15th, 1916.
SHEDD, FRANK EDSON. Elected Member, February 6th, 1907; died September 22d, 1916.

Total Membership of the Society, November 2d, 1916,
8 162.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(October 3d to November 1st, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 10c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age*, New York City, 10c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.

(56) *Transactions*, Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian*, London, England, 5d.
(58) *Proceedings*, Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings*, American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering*, Indianapolis, Ind., 25c.
(61) *Proceedings*, Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron*, Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings*, Inst. C. E., London, England.
(64) *Power*, New York City, 5c.
(65) *Official Proceedings*, New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting*, London, England, 6d.
(67) *Cement and Engineering News*, Chicago, Ill., 25c.
(68) *Mining Journal*, London, England, 6d.
(69) *Der Eisenbau*, Leipzig, Germany.
(71) *Journal*, Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs*, Iron and Steel Inst., London, England.
(72) *American Machinist*, New York City, 15c.
(73) *Electrician*, London, England, 18c.
(74) *Transactions*, Inst. of Min. and Metal., London, England.
(75) *Proceedings*, Inst. of Mech. Engrs., London, England.
(76) *Brick*, Chicago, Ill., 20c.
(77) *Journal*, Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen*, Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten*, Vienna, Austria.
(80) *Tonindustrie Zeitung*, Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen*, Wiesbaden, Germany.
(82) *Mining and Engineering World*, Chicago, Ill., 10c.
(83) *Gas Age*, New York City, 15c.
(84) *Le Ciment*, Paris, France.
(85) *Proceedings*, Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting*, Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer*, Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings*, Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions*, Inst. of Naval Archts., London, England.
(91) *Transactions*, Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin*, Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie*, Paris, France, 4 fr. 50.
(95) *International Marine Engineering*, New York City, 20c.
(96) *Canadian Engineer*, Toronto, Ont., Canada, 10c.
(98) *Journal*, Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings*, Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs*, Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker*, New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens*, Wiesbaden, Germany.
(103) *Mining and Scientific Press*, San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer*, London, England, 6d.
(105) *Metallurgical and Chemical Engineering*, New York City, 25c.
(106) *Transactions*, Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung*, Zürich, Switzerland.
(108) *Iron Tradesman*, Atlanta, Ga., 10c.
(109) *Journal*, Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal*, Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas*, San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung*, Leipzig, Germany.
(113) *Proceedings*, Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal*, Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal*, Engrs.' Club of St. Louis, St. Louis Mo., 35c.
(116) *Blast Furnace and Steel Plant*, Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

The Operating Machinery of the Willamette River Drawbridge, near Portland, Oregon.* Byron B. Carter. (4) Sept.
Quebec Bridge Central Span.* G. H. Duggan. (96) Sept. 14.
The Quebec Bridge Disaster.* (46) Sept. 23; (12) Sept. 15; (11) Oct. 13.
Erection of the Suspended Span, New Quebec Bridge.* G. V. Davies and N. C. McMath. (86) Sept. 27.
Novel Electrically Operated Lift Bridge.* (86) Sept. 27.
Heating Materials for Bridge Paving in Cold Weather. C. B. Freeman. (86) Sept. 27.

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Bridges—(Continued).

Progress on Bloor Street Viaduct, Toronto.* (96) Sept. 28.
Reconstructing an Old Bridge.* (87) Oct.
Pertinent Remarks on the Quebec Bridge Accident. W. P. Parker. (2) Oct.
Careless Work Causes Concrete Bridge Failure.* (13) Oct. 5.
Computing the Stresses in the Quebec Rocker Casting.* (13) Oct. 5.
Creosoted Timber Floor Fire Racks, Missouri Bridge.* (13) Oct. 5.
New Roller Shoe for Bridges Prevents Tipping.* (13) Oct. 5.
New Standard Specifications Issued by Ontario Ry. and Municipal Board. D. A. Molitor. (96) Oct. 5.
Strengthening an Alley Bridge. (13) Oct. 5.
Wind Cripples Bridge Portals and Lower Laterals.* Clifford Older. (13) Oct. 5.
Bridge Wrecked by Runaway Car Derailed at Curve.* (13) Oct. 12.
Capping Old Bridge Piers Under Railway Traffic.* (13) Oct. 12.
Culverts—Their Location and Construction.* C. D. Norton. (96) Oct. 12.
The Caronte Viaduct.* (11) Serial beginning Oct. 13.
New Mississippi River Bridge at Memphis.* (15) Oct. 13.
Building Second Half of the Susquehanna Bridge.* (13) Oct. 19.
Defective Bascule Bridge. (13) Oct. 19.
Concrete Bridge Completed from Suspended Forms.* F. R. Goodman. (13) Oct. 26.
Erecting Highway Bridges Under Traffic; Michigan. C. V. Dewart. (13) Oct. 26.
Theory and Tests Presented for Design of Sand Boxes to Lower Arch Centers.* Frank P. McKibben. (14) Oct. 28.
Le Nouvel Accident du Pont de Québec Chute de la Travée Centrale au Moment de sa Mise en Place par Soulèvement.* Georges Dupont. (33) Oct. 14.

Electrical.

Mechanical Problem of Electric-Power Transmission Line Conductors.* A. T. Arnall. (63) Vol. 201.
Dynamo-Electric Machinery, 1878–1916.* Miles Walker. (73) Sept. 15.
Long Distance Telephony. B. S. Cohen. (73) Sept. 15.
Modern Electric Searchlight Protectors.* J. H. Johnson. (12) Serial beginning Sept. 15.
Radiotelegraphy: A Retrospect of Twenty Years.* J. A. Fleming. (73) Sept. 15.
Recent Progress in X-Rays and Radiography.* G. W. C. Kaye. (73) Sept. 15.
Some Characteristic Curves of a Poulsen-Arc Generator.* N. W. Mclachlan. (73) Serial beginning Sept. 15.
Speed of Submarine Telegraphy.* Edward Raymond-Barker. (73) Sept. 15.
Story of the Submarine Cable.* Charles Bright. (73) Sept. 15.
Laws of Variation of Resistance with Voltage at a Rectifying Contact of Two Solid Conductors, with Applications to the Electric Wave Detector.* D. Owen. (Abstract of paper read before the Physical Soc. of London.) (73) Sept. 22.
Mercury Arc Rectifier for Charging Small Batteries.* C. N. Green. (From paper in *General Electric Review.*) (26) Sept. 22.
Method of Splicing High Power Submarine Electric Cables.* (86) Sept. 27.
Higher Harmonics of Induction Due to Winding Distribution.* A. H. Mittag. (From the *General Electric Review.*) (73) Sept. 29.
Alternating-Current Service for an Office Building.* Charles Klapper. (27) Sept. 30.
Fixture Selection and Maintenance in Office Building Lighting.* (27) Sept. 30.
Motor Drive for Operating Steel Rolling Mill.* William Knight. (27) Sept. 30.
Production of Small Dry Batteries. C. F. Burgess. (Paper read before the Am. Electrochemical Soc.) (27) Sept. 30.
Cost *vs.* Upkeep of Direct-Current Motors. A. M. MacCutcheon. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (116) Serial beginning Oct.
Power Company's Problem in the Electric Supply for Large Single-Phase Load. W. C. L. Eglin. (42) Oct.
Single-Phase Power Production.* E. F. W. Alexanderson and G. H. Hill. (42) Oct.
Single-Phase Power Service from Central Stations.* R. E. Gilman and C. Le G. Fortescue. (42) Oct.
Operating Data on Electric Blooming Mill.* E. S. Jefferies. (Paper read before the Assoc. of Iron and Steel Elec. Engrs.) (116) Oct.
Supply of Single-Phase Loads from Central Stations.* Philip Torchio. (42) Oct.
Cost of Placing 53 Concrete Foundations for Electric Light Standards.* H. R. Ferris. (86) Oct. 4.
Tunnels for Electric Cables. (13) Oct. 5.
Electric Power in a Marble Quarry at Proctor, Vt.* (12) Oct. 6.
Radio-Telegraphy Over Great Distances.* W. Duddell. (73) Oct. 6.
Use of Metal Slot Wedges in Induction Motors.* B. B. Ramey. (Abstract from the *Electric Journal.*) (73) Oct. 6.
The Alkaline Storage Battery. L. C. Turnock. (Abstract of paper read before the Am. Electrochemical Soc.) (27) Oct. 7.
Condenser Lightning Arrester for Electric Railway Protection. Q. A. Brackett. (17) Oct. 7.
Cost of Rural Lines and Revenue Therefrom. (27) Oct. 7.

* Illustrated.

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Determining First Cost of Edison Tube System.* Julian Loebenstein. (27) Oct. 7.
Illumination at Salt Lake City.* B. W. Mendenhall. (111) Oct. 7.
Recent Installations Made by Winnipeg Company.* H. A. P. Langstaff. (27) Oct. 7.
Effect of Imperfect Dielectrics in the Field of a Radiotelegraphic Antenna.* John M. Miller. (Abstract from *Bulletin*, Bureau of Standards.) (73) Oct. 13.
Electricity Supply in Bethnal Green.* (26) Oct. 13.
On the Wave-Forms of Magnetising Current and Flux Density for a "Stalloy" Magnetic Circuit.* B. Hague and S. Neville. (73) Oct. 13.
Characteristics of Iron and Steel Conductors.* C. E. Oakes and Winfield Eckley. (27) Oct. 14.
Load Dispatching by New England Power Company.* (27) Oct. 14.
New Armature Machine.* (45) Oct. 14.
Operating a Station Under Unfavorable Conditions.* (27) Oct. 14.
Some Electric Water-Heating Problems Solved.* A. J. Kercher. (111) Oct. 14.
Electric Power Tranmission Economics. G. P. Roux. (From *General Electric Review*.) (96) Oct. 19.
Erecting Steel Transmission Towers with Ginpole.* L. R. Allison. (13) Oct. 19.
Electrical Refrigeration in a Cafeteria.* H. N. Sessions. (111) Oct. 21.
Hot Spots in Synchronous Converter Armatures.* A. E. Hanson and C. A. Corney. (27) Oct. 21.
Layout and Tests of an Alabama Cotton Mill.* George Wrigley. (27) Oct. 21.
Output Limitations in Direct-Current Machines.* Alex Gray. (27) Oct. 21.
Rationalization of the Magnetic Units. J. H. Dellinger. (27) Oct. 21.
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Propelling Machinery for Ships. W. J. Drummond. (75) May.
Oil Burners with Natural Draught on U. S. S. *Fulton*.* (12) Sept. 29.
Liquid Compass.* (11) Sept. 29.
Efficiency of Propulsive Machinery and Late Developments in Naval Engineering.* H. C. Dinger. (55) Oct.
The Twin-Screw Motor-Ship *Peru*. (11) Oct. 6.
Steel Anchors for Merchant and Battleships. E. F. Cone. (20) Oct. 12.
The U. S. Submarine Tender *Bushnell*. G. E. Davies. (Paper read before the Am. Soc. of Naval Engrs.) (12) Oct. 13.
New Train Ferry for New Orleans.* (12) Oct. 13.
United States Coast Survey Steamer *Surveyor*.* (13) Oct. 26.

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Analytical and Experimental Investigations Relating to Centrifugal Pumps.* Hubert Mawson. (63) Vol. 201.
Flow of Air Through Nozzles.* T. B. Morley. (75) May.
Chisels.* Henry Fowler. (75) May.
Spur-Gearing.* Daniel Adamson. (75) May.
Composition of the Exhaust from Liquid Fuel Engines.* R. W. Fenning. (75) May.
The Screw. (108) Sept.
Spanning the Brazos River with Two 10-in. Gas Mains. C. R. Sutton. (108) Sept.
Gas-Furnaces and Their Utility.* Ralph Halkett. (Paper read before the North British Assoc. of Gas Mgrs.) (66) Sept. 5; (22) Sept. 15.
Mixing Carbonates with Coal.* A. Rollason. (22) Sept. 15.
Electrically-Driven Coal-Handling Plant.* H. H. Broughton. (73) Sept. 15.
Turret Lathe for Bars and Milling Machine.* (11) Sept. 15.
Steam Storage Locomotives.* (12) Sept. 15.
The Annealing of Arsenical Brass. C. H. Mathewson and E. M. Thalheimer. (Paper read before the Inst. of Metals.) (11) Sept. 22.
Starting Diesel Engines with Low Compression.* W. H. Watkinson. (Paper read before the British Assoc.) (11) Sept. 22.
Fuel Economy on the North-East Coast as a Result of Electric Power Supply. R. P. Sloan. (Paper read before the British Assoc.) (11) Sept. 22.
Fuel Economy; First Report of a Committee by the British Association. (47) Serial beginning Sept. 22; (11) Sept. 22.
Limit Gauges. R. T. Glazebrook. (Abstract of paper read before the British Assoc.) (73) Sept. 22.
Coal Handling on the Norfolk & Western Railway. (45) Sept. 23.
History of a Successful Jig.* F. B. Davenport. (45) Sept. 23.
Michigan Test Shows That Gas Coals Can be Exposed to Weather for 5-Year Period Without any Deteriorating Effect. A. H. White. (Paper read before Michigan Gas Assoc.) (24) Sept. 25.
Four General Conditions Determine Cost of Manufacturing Gas. H. W. Douglas. (Paper read before the Michigan Gas Assoc.) (24) Sept. 25.

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* Illustrated.

Mechanical—(Continued).

Many Unique Piping Systems Developed in Connection With the Gas Illumination of the Philadelphia Civic Exposition.* C. S. Snyder and F. H. Gilpin. (Paper read before the Illum. Eng. Soc.) (24) Sept. 25; (83) Serial beginning Oct. 2.
The "Direct" Process for the Manufacture of Sulphate of Ammonia and the Storage of Ammoniacal Liquor. W. S. Curphey. (66) Sept. 26.
Design of Steel Stacks.* W. A. Hitchcock. (96) Sept. 28.
Stationary Boilers Fired by Pulverized Coal on the Missouri, Kansas & Texas. (15) Sept. 29.
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PAPERS AND DISCUSSIONS

NOVEMBER, 1916

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AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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Vol. XLII. NOVEMBER, 1916. No 9.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

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THE VALUATION OF LAND

By L. P. Jerrard, Jun. Am. Soc. C. E.

To be Presented December 20th, 1916.

Synopsis.

In this paper attention is called to the fact that, in the extensive valuation work which has been carried on by engineers in late years, the item of land in an inventory has been turned over to real estate dealers. The contention is then made that, even where the services of reliable and well-informed dealers are secured, their appraisals are not entirely satisfactory, and that it is well within the province of the engineer to check the values submitted to him, or even to make the determination of land values himself.

After some discussion of this point, there follows an exposition of the methods and procedure to be used in valuing land, a brief outline of which is as follows:

The principles of land values;
Sources of data regarding land values;
Method of utilizing the data;
Rules for long and short lots;
Corner lot rules;
Plottage;
The cost of acquiring land;
Values based on special utilization;
The valuation of railroad land;
The cost of land appraisals.

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

In recent years there has been a great increase in the demand for valuation of physical property of every description. One great stimulus has perhaps been the organization of public bodies for the purpose of investigating and regulating semi-public corporations, but modern methods of accounting and keeping records are also an important factor. The work of making these valuations has naturally fallen into the hands of engineers, owing to the fact that they, more than any one else, have had to do with the design, construction, and in many cases the selling, of the structures and equipment for which an appraisal is demanded. The various items of inventory—of which, with some exceptions, the most common is land—fall within the knowledge of an electrical, mechanical, civil, or gas engineer.

The item of land appears in almost every inventory, and its importance in appraisal work may be seen from the fact that its value ordinarily constitutes from 5 to 50% of the total value of a utility. It is probably customary for an engineer, in handling a valuation proposition, to feel that the land is somewhat out of his field, and to turn this part of the work over to one or more real estate dealers. In this paper the contention will be made that, even where the services of reliable and well-informed dealers are secured, their appraisals are not entirely satisfactory, and that it is well within the province of an engineer to check the values submitted to him, or even to make the determination of value himself. In some of the greater cities large real estate offices maintain highly organized appraisal departments and, unquestionably, no one is better qualified to make land valuations in certain territory than they are, but it is held that in the country at large the average real estate dealers' appraisals are likely to be in error, due to carelessness, prejudice, or incompetence. It is proposed to show that land values are fixed by more or less definite forces, and to indicate how, by the systematic collection and application of data, a man unfamiliar with land values, as a dealer or even as a near-by resident, may obtain reliable appraisals.

The development of the methods suggested herein should be useful, not only in valuation work, but also in acquiring land for utilities, and especially in cases where controversies arise. In a contest, a real estate broker testifies that he has been a land dealer for a certain number of years, that he has platted and sold land in the vicinity of the tract in question, and that in his opinion the tract is worth a certain sum. In

some cases the very sales he himself has made would, if analyzed, disprove his contention. In what a multitude of cases have not city and county authorities, railroad companies, and other corporations been forced to pay exorbitant sums for land on evidence of this character! In no case may an appraiser gather data enough actually to prove the value of a tract of land, and in the end his conclusions represent his opinion only, but he can present logical reasons for his opinion, and can generally submit enough facts to define a value within narrow limits.

In approaching this subject, it should be borne in mind that land has a value as a result of the operation of definite economic, political, or social forces, and that changes of value take place by reason of similar forces. The location of cities does not occur at random, nor does their growth take place by chance; likewise, the development of farming communities is regulated by their natural facilities. It is the consideration, then, of the factors which affect land values to which the writer will proceed.

The true value of land is the ground rent capitalized. The ground rent is the net income which remains after paying the taxes on the land and the taxes, depreciation, interest, and maintenance on all improvements. The market value may be entirely different from the true value, as it is based, not only on the ground rent capitalized, but on the future prospects of the land's utilization. Farm land differs from city land in that the fertility of the soil, in addition to the advantage of location, is a source of ground rent. Farm land values are comparatively simple, however, and will be treated briefly before taking up city land values, as the latter are much more important.

The value of farm lands depends primarily on the fertility of the soil. Other factors are the topography, water supply, climatic conditions, and the development of the community as regards markets, highways, schools, villages, etc. The advantages of location consist in nearness to cities, railway stations, and schools. The value of farm land is comparatively low and the range of values small. The factors just mentioned vary but little over large areas, and consequently the change in values is gradual. The problem of determining farm land values, therefore, is comparatively simple, because any data which may be obtained are generally applicable over a large district.

The Structural Development of Cities.

The problem presented by cities is much more complex. In the first settlement of new territory, land has no value. A settler has his choice of numerous locations, and occupies any tract that suits his fancy. As other settlers appear, however, there comes a time when there is a difference in desirability between two tracts, due to their location. It is at this point that value arises in the land having a superior location, and it becomes a source of ground rent. As the community grows, more distant lands come into use, a larger area of land has a value, and the value of the best location is forced higher. When the proportions of a city are reached, the grades of land are very numerous, and they are occupied by a variety of utilities. City land is useful only as a site for buildings, and advantages of location govern the values entirely. Any location in the city may be sought by any utility, and the land goes to the one which can make it yield the highest ground rent and, therefore, pay the greatest price for it.

City land may be divided roughly into the following classes as regards utilization:

Distribution.—Retail stores, wholesale stores, railroads.

Administration.—Banks, office buildings, public buildings.

Production.—Factories.

Residence.—Dwellings, tenements, apartments, hotels.

There are other utilizations, such as theaters, hospitals, libraries, etc., which do not fall readily under these classes, but they do not form a large percentage of the total number of utilities. For each of the utilities in this classification there is, with respect to other utilities, a portion of a city within which it is almost forced to locate.

In retailing, the seller must draw the buyer into his establishment. He seeks a location where the largest number of prospective customers will pass, and, consequently, retail stores gather at the heart of the city. Wholesale dealers locate where transportation facilities are best, and as close as rentals will warrant to any retailers whose business they may seek to hold or obtain. Railroads procure sites close to the business center in order to secure passenger traffic, and their freight terminals are located in the wholesale and manufacturing districts. Banks and office buildings are found in the business center, but they can scarcely compete with retail stores for the best locations. Manu-

facturing, to some extent, has the same requirements as wholesaling, but, in addition to railroad facilities, their labor conditions must be considered.

The basis of business values is strictly economic, the land going to the highest bidder, but the basis of residence values has a social element. The wealthy class select the best locations, near parks, easy of access, and free from nuisances. Those of lesser means take locations as near them as possible, and the poorest people are obliged to live in the outskirts of the city or in undesirable places near tanneries, railroad yards, gas plants, etc. Apartment houses are distributed about the same as dwellings; and hotels locate near the retail stores, theaters, and passenger terminals.

The conspicuous feature in cities is the tendency of utilities in the same business to cluster together. The influences which favor one are favorable to another, and, moreover, each establishment endeavors to benefit by the business which other concerns draw. A buyer in a city may visit a number of wholesale houses by traversing a small district, and a jobber located in some other part of the city would probably not receive his attention. In every large city, then, there will be found at the center a business section, certain portions of which are occupied by different groups of utilities, such as retail stores, banks and financial institutions, jobbing houses, etc. Surrounding the business center are sections occupied by the several classes of residence structures, by storage warehouses, factories, railroad yards, and many other utilities. The lines of demarcation between these sections are generally not well defined, as the change from one class of utilization to another is for the most part gradual. It is not uncommon, however, to find two distinct classes of utilization separated by a single street; and barriers, such as a river or a railroad line, often constitute sharp division lines.

The increase in population, the changes in style of architecture and types of construction, and the constant depreciation of buildings cause a continuous movement of utilities from one district to another. In a fine residence section the houses eventually become old and out-of-date, and, as a result, more modern dwellings are built in new districts elsewhere in the city. The old section soon begins to lose its reputation as a fashionable district, the wealthy people gradually move out, the vacated dwellings are use for boarding houses, and the section suffers a decline in land values, even as a rise in values is experienced in the

new district. It is possible for real estate men to gain control of a district, and, by platting it in a suitable manner, making street and park improvements and placing building restrictions on all lots sold, to develop a good residence section. Similarly, by filling in low lands or providing railroad or harbor facilities, a manufacturing or shipping district may be fostered. Frequently the movement of groups of utilities, and consequent changes of land value, are regulated by activities along such lines. In many cases the movement of utilities from one district to another is guided more by the natural growth of the city and the development of its transportation systems, and cannot be influenced as in the foregoing instances. Business property is the least susceptible to such influences.

Business remains on level ground and where topography does not interfere, the retail section moves in the direction of the best residence section. The reason for this is that the residents of such a section represent the heaviest buyers, and their custom is sought by all shops, not alone for the value of their patronage, but also by reason of the fact that all classes go to the shops where the wealthy class trades. The advance of a retail section toward a residence section involves the movement of banks and offices into new districts. The buildings vacated by shops, offices, and banks must necessarily succeed to a lower utility, such as wholesale houses and factories, and these are often followed by tenements and vacancies, so that land once the best in the city sometimes drops to a low value. The point of highest value is constantly moving, and, unless the increase in population is sufficient to overcome the tendency, the land behind this movement suffers a decrease in value.

City Land Values.

From the business center, the main traveled streets project axes of higher value into the outlying territory. As a rule, values grade down regularly from the point of highest value at the business center to the outskirts of the city, and also grade down on either side of the main traveled axes radiating from the heart of the city. This general scheme of values is modified by the location of railroads, bridges, parks, and the different classes of utilities, and also by the topography, kind of platting, extent of street improvements, etc. It is not common to find sharp differences in the values of two adjoining properties. Where a district of low utility adjoins one where land values are compara-

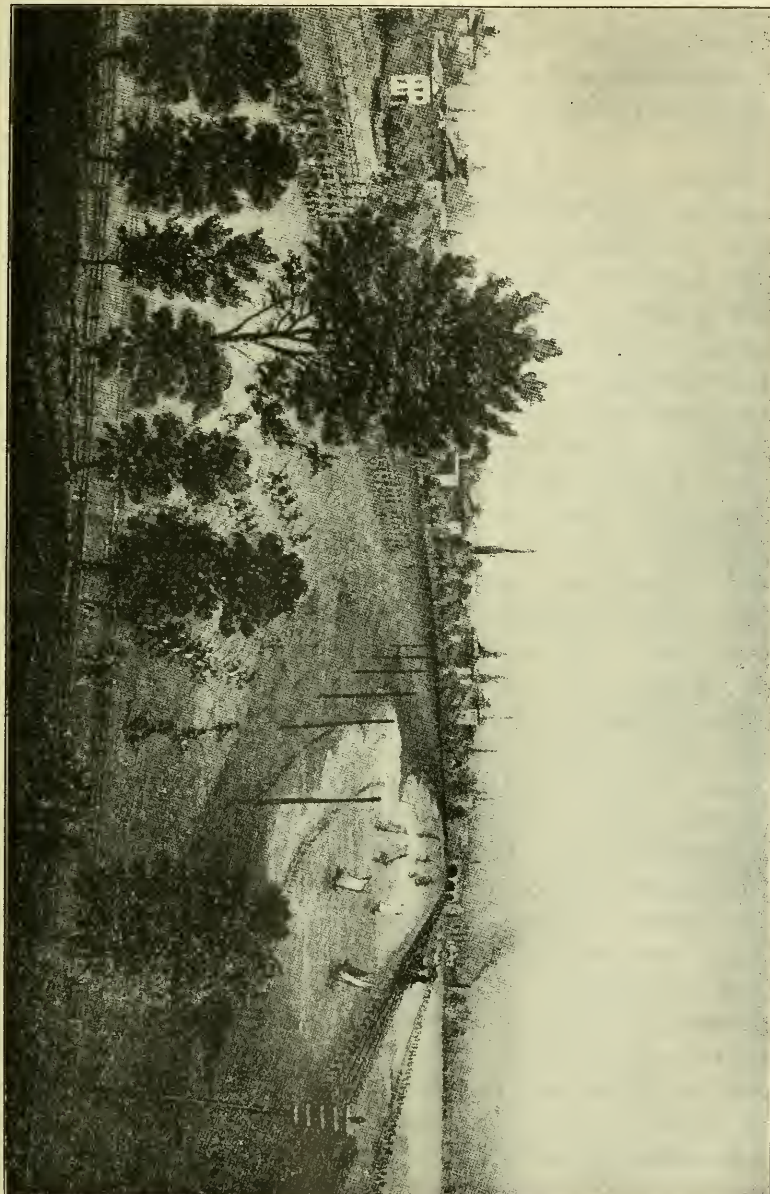


FIG. 1.—MICHIGAN AVENUE, CHICAGO, FROM PARK ROW, IN 1864. THE BUSINESS CENTER OF A CITY MOVES TOWARD THE BEST RESIDENCE SECTION.

tively high, the low-class land near the boundary is of greater value than the remainder of the district, owing to the proximity of higher values, and, correspondingly, the high-class land near the boundary reflects to a certain extent the low values near-by. Marked changes of value take place, not by sudden variation, but by degrees, over a distance of several blocks.

The total land value of a city depends primarily on the population, but is influenced to so great an extent by the city's wealth and other factors that comparisons between cities of the same population, as to either the total land value or the value of highest priced land, offer considerable variation. It is believed that the range of values in Fig. 2 will cover the conditions in all except a very small percentage of cities. The lower values represent more nearly the normal conditions, and the higher values occur in cities where there is a large transient population or where the business district is restricted. All factors which tend toward the expenditure, in a city, of money which is earned elsewhere, raise the value of business land. For instance, the location, in a city of 25 000 people, of a university with several thousand students would materially increase business land values above those of other cities of the same size. In determining the population of a city, there should be considered such suburbs as are close enough to constitute a part of the city proper. The 1910 census shows the population of Boston to be about 670 000, but the addition of Cambridge, Somerville, Winthrop, and other communities which directly adjoin the city and are closer to the business center than some parts of Boston proper, brings this figure up to nearly 1 000 000. Entering Fig. 2 with this latter figure the value of the best business land is seen to range from \$9 000 to \$15 000 per front foot and, when the great tributary and transient population of the city is considered, one would expect to find there, as is in fact the case, values corresponding to the higher figure.

It will be seen from the foregoing that an investigation of land values generally involves a study of the forces at work in a city's development, the land requirements and distribution of its utilities, and the strength and direction of the structural movements which are constantly taking place. The extent of such a study would depend, of course, on the land under consideration. In valuing a single lot in a residence section, such preparation would not be called for, but, in the case of high-priced business land, it is necessary to be informed on these points.

For the purposes of this paper the "market value" of land will be considered as the ordinary exchange price that one party would pay another for a farm, city lot, or other tract of land, under normal conditions, that is, when the purchaser is not compelled by circumstances to pay an excessive price nor the grantor to sell at a sacrifice. The market value will not include additional amounts which are often paid for plottage, severance charges, or damages; also, the term "front foot" will be made to mean a strip of land having a frontage of 1 ft. on a street and a depth of 100 ft. measured at right angles thereto. The unit used in measuring city land varies in different parts of the country. In some places it is the custom to use the front foot of 100-ft. depth, or some other depth, and in other places the square foot is the unit. Those accustomed to think of land values by the square foot can readily convert the figures in mind to the front foot as used herein by multiplying by 100.

Sources of Data for Determining Land Values.

In making land appraisals, the following classes of information are available:

Inspection and general study.
Sales of real estate.
Tax assessments.
Rentals.
Value of opinions of land dealers.
Value of opinions of land owners.
Character of buildings, as an index to land values.
Real estate for sale.

Inspection and General Study.—In connection with any property, there should be obtained at the outset all information with regard to the dimensions of the tract, the accuracy of the survey, the condition of the title, the amount of taxes and special assessments due, and the existence of mortgages or restrictions as to the use of the land. An inspection is generally necessary in order to determine the extent and condition of street improvements, and the nature of the property as regards topography, filling, protection of water frontage, etc. A general study also involves some investigation of the district in which the property is located and of the city's development and structural growth, as heretofore outlined. A knowledge of general conditions enables an

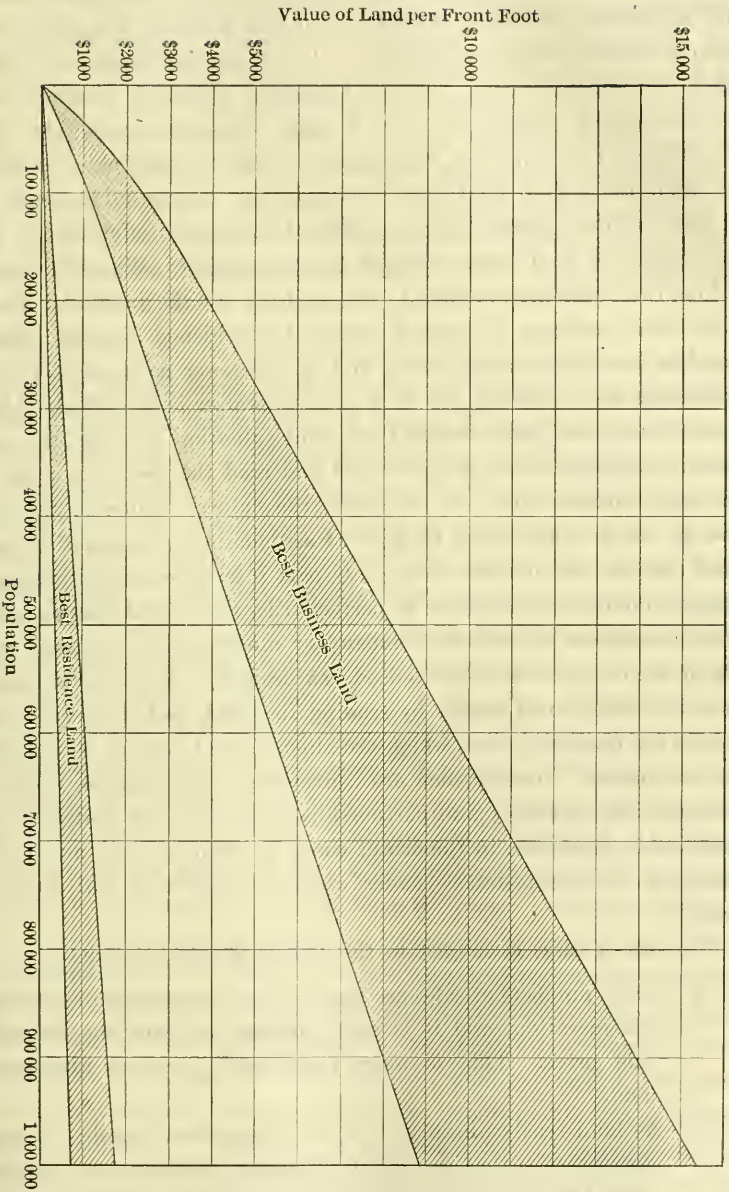

Value of Land per Front Foot
$1000
$2000
$3000
$4000
$5000
$10 000
$15 000
100 000
200 000
300 000
400 000
500 000
600 000
700 000
800 000
900 000
1 000 000
Best Business Land
Best Residence Land
Population

FIG. 2.

appraiser to make use of data which are not directly applicable to the land in question, and often establishes limiting values on a tract of land before a detailed study is undertaken. It is always advisable to be provided with a map showing, not only the parcel of land in question, but the surrounding district for a good many blocks on every side. By recording on this map sales, assessments, rentals, topographic features, etc., their bearing on land values may be most clearly understood.

Sales of Real Estate.—Actual sales of real estate offer one of the best criteria of land value available to an appraiser. Where they can be found in sufficient numbers to form a basis for the judgment, there is no better evidence of market value. In residence districts, where transfers are always taking place, and in the newer portions of a city, where sales are numerous, the work of an appraiser is simplified. After a list of sales has been obtained for land valuation purposes, the appraiser should go to the public record and read the deeds, in order to cull out transfers which do not show true values. Some of the reasons for which sales should be rejected are nominal consideration, material reservations or restrictions, only part interest conveyed, personal property included, conveyance to perfect title, trade, deal between relatives, conveyance to railroad company or municipality, scattered parcels in one conveyance, sheriff's deed, tax deed, etc. These facts cannot always be determined simply by reading the deed, and there are other reasons for rejecting a sale which are almost sure to escape observation by that method. Among such are conveyances by swindlers, fictitious considerations, company and partnership deals, and land contracts. It is advisable, therefore, in important cases, to learn as much as possible regarding the circumstances under which a transfer of real estate is made.

The use of sales is subject to the following disadvantages:

1.—Large numbers of sales are recorded with a nominal or fictitious consideration, and it is often difficult to learn the *bona-fide* sale price. This is more particularly true of high-priced land.

2.—As land reaches high values, the proportional number of sales decreases, so that in certain classes of property such as high-class business land, or dock property where harbor space is limited, the sales data are very meager.

3.—Sales of real estate often include buildings which must be separated in order to determine the sale value of the land alone. In cheap properties many vacant lots are sold, but where land reaches a high value it is not allowed to stand idle, and a sale price is sure to include more or less extensive improvements. In a considerable portion of the high-priced property that comes to sale, the improvements are old, poorly designed, or not suited to the location. These propositions generally involve the wrecking or remodeling of a building, and the apportionment of the sale price between value of improvements and value of land is a doubtful process.

It may be seen, therefore, that sales are more directly useful in appraising cheaper lands, such as ordinary residence sections, where values are low and changes of value gradual, but that their availability decreases in somewhat the same proportion as land increases in value.

Tax Assessments.—Assessments of real estate for taxation purposes are generally considered to be of little or no use as a guide to land values, and it is true that the average city assessment exhibits many irregularities. The assessments are made, however, by men whose particular business it is to study the values in a certain section, and as most of them gain great familiarity with their districts, the figures determined by them are a valuable aid to the judgment. Assessments may be faulty in two particulars: first, in that the different parcels are not assessed on the same basis; and, second, in that the whole district is not assessed at full market value, but at some percentage thereof. The best way to determine whether an assessment is well equalized is to reduce the figures in the section to the same unit, such as dollars per front foot, per acre, or per lot, and plat them on a map. Irregularities show up very clearly on such a graphical representation. As a rule, however, an assessment will be found to be fairly good as regards the comparative value of different parcels, especially where it has been developed during a period of years. Taxpayers are constantly comparing their assessments with those of their neighbors, and, as marked differences meet with complaint until rectified, the tendency is always toward better equalization. It should be noted that not all assessments separate land and buildings, for in many communities the sum of the two appears as one item on the public records. In such cases the assessment

on land alone cannot be obtained, unless, as is often the case, it is obtained from the private records of the assessor.

It is possible, then, where land assessments are available, for an appraiser to make an examination of them and, by the elimination of irregularities and discriminations, determine a fair assessed value for a given piece of land. It only remains, then, to determine what percentage the assessment bears to the true market value. This is done by gathering *bona-fide* sales of property, ascertaining the assessed value of such properties, and computing the ratio of assessed value to market value. For this purpose it is possible to use sales throughout a small area surrounding the tract in question, or a ward, or even an entire city. This method amplifies the use of sales data very materially, for it permits the use of sales which have no direct bearing on the land being appraised, and, moreover, is not affected to such a large extent by the fact that real estate sales involve the value of improvements. Assessments, therefore, when carefully studied and used in connection with land sales, constitute valuable evidence with regard to land values.

Rentals.—If ground rent is determined it is possible to capitalize it and arrive at a value for the land. This process involves gathering considerable data and the use of very good judgment in choosing a rate of capitalization. Ground rent is computed by deducting from the gross rental the taxes on the land, and the taxes, insurance, interest, maintenance, and annual depreciation on the improvements. There are modifications of this procedure by which the gross rental, or the gross rental less certain items, is capitalized, and the rate of capitalization is increased to allow for the items just mentioned which are not deducted. There is a disadvantage in using gross rentals, however, for when capitalized they represent the land and buildings together, and there remains the difficulty of separating the value of land from that of the total improved property. On the other hand, the amount of ground rent as computed may fluctuate greatly, due to the influence of management, and it is necessary to know that a property is well administered, lest the ground rent as determined be too low or even nonexistent. It is also necessary to use current rentals, for rentals agreed upon at some previous time may reflect incorrect values, and this is especially true where land values are changing.

The rate of capitalization follows the same course as the yield on securities, and depends on the safety and permanence of the earning

power. The rate ranges from 4% for the best property in large cities up to 8 and 10% for poor properties in small cities, and even higher for land suitable only for temporary or disreputable utilization. The rate varies in different cities, and, as a rule, is lower in the Eastern States than in the West or South. In a district where land values are increasing, the rate of capitalization is below normal, and where values are decreasing, it runs very high. As previously stated, the use of rentals requires care and good judgment in order to obtain satisfactory results.

Value of Opinions of Land Dealers.—The most common method of ascertaining the value of land is to consult real estate dealers, but, in a large number of cases, their figures are found to be unsatisfactory. The average real estate dealer's appraisal represents an inspection, some thought on such sales and rentals as he is familiar with, and an interview possibly with some other dealer, but no systematic collection and presentation of data. Sometimes great carelessness is displayed in their work. As an instance may be cited the case where several dealers made valuations of a piece of dock property, ranging from \$75 to \$200 per front foot. Some of them evidently overlooked the fact that the property was not accessible from any street except by passing a long distance over land belonging to another owner, for, in consideration of this fact, the tract was transferred for \$66 per front foot. As a rule, the successful real estate dealers' principal assets are nerve and salesmanship. They do not want honestly to know values, but to make sales. They possess an advantage, however, in their knowledge of sale and rental figures, and it is often necessary to gain their co-operation in order to obtain this information. Real estate dealers are generally optimists, and in their opinions often incline to high values, especially in the districts where they are selling lands. Ordinary prejudice, however, does not account for the almost incredible variation which is sometimes found in the opinions of real estate men regarding the same piece of land, which indicates that this class of information may be far from correct and should be weighed carefully before being accepted as evidence on which to base judgment.

Value of Opinions of Land Owners.—A land owner nearly always has a definite opinion as to the value of his holdings, even though he is not in the market for land, either as a buyer or a seller. This is held to be important information by some authorities on the ground that it is the opinion of land owners which fixes the market value of land. The

probabilities, however, are that the converse is much more often the case, and the opinion of the land holder is fixed by such knowledge as he obtains regarding sales. It is believed that in a great number of cases a land holder is not well enough informed to pass reliable opinions on land values, and that when he is competent it is difficult to obtain from him an honest expression. This class of information can be obtained readily, and should be given some consideration.

Character of Buildings as an Index to Land Values.—The cost of buildings is in a measure an index to the value of the lands which they occupy. In a large proportion of the buildings constructed for business purposes, the cost is about equal to the value of the land. There is, of course, great deviation from this rule, but marked departure is almost always accompanied by financial loss. A cheap building on expensive land is unable to earn an income proportionate to the high land value; and an expensive building on cheap land must necessarily be located outside the district where structures of its class are in demand. On this basis Table 1 has been prepared, showing the value of land occupied by the ordinary types of business buildings, in dollars per front foot, but it should be useful only for very rough estimating. There are numerous instances where there is a great variation in the value of buildings along a street on which lots have approximately the same value, and in such cases the tendency is for the land values to correspond more nearly to those of the highest structures. Exceptions to the general rule are frequent, as, for instance, where cheap structures are erected on good land to serve but a short time, while waiting a better opportunity to make permanent improvements on the property.

TABLE 1.

Size of building.	Construction.	Average value of land per front foot.
2-story	Brick and frame.	$150 to $200
3 "	" " "	250 to 350
4 "	" " "	400 to 500
5 "	" " "	600 to 800
6 "	Slow-burning.	1 000 to 1 500
8 "	" "	2 000 to 3 000
10 "	Tending to fire-proof.	3 500 to 5 500
12 "	Fire-proof.	5 500

Real Estate for Sale.—Although there may be no sales of real estate in a district, it is generally possible to find property which is on the market, and obtain an offer of sale. Such an offer throws light on land

values, but should generally be considered as establishing a maximum figure. A party in making an offer usually endeavors to get a high price at first and is obliged to lower his figure before a transaction is finally made. Such offers, consequently, represent values in excess of the market value. They constitute valuable information, however, and have the additional merit of being readily obtainable in the majority of cases.

Determination of Value.

Information bearing on land values may often be found by investigating the expert testimony given in damage cases and other Court actions or hearings, Probate Court records, inheritance tax appraisals, mortgage records, and tax disputes. In valuing land, there may be utilized one or more of the classes of information which have just been discussed. In a district where good sales are plentiful, a brief study of the transfers may be sufficient. As lands reach high values, however, the information bearing on them, not only exists in smaller quantities, but is more difficult to obtain, and often there are few enough data on which to base judgment, even after a careful investigation. The final determination of a market value is ultimately a matter of the judgment of the appraiser, and it is for him to decide in each case what information is required, and just what weight should be given to all the evidence finally obtained.

In summing up it may be said that the important steps in determining the market value of land are as follows:

1.—A thorough investigation of all conditions affecting the land in question, in order that no important considerations may be overlooked, as, for instance, the lack of street connections, in the case already cited.

2.—A systematic and thorough collection of information.

3.—A graphical representation of the data gathered, for by no other means may the relation which values bear to each other be so readily understood.

4.—Determination of value after weighing all evidence.

It should be remembered that the market value of a given piece of land is not a definite sum, and cannot be estimated with absolute accuracy. Several unprejudiced men, all working with the same data, will not obtain similar results. In certain cases it may be possible to

establish a definite market value on cheap vacant lots, but, when property values run into several thousand dollars, reliable estimates will vary 5%, and in complex situations 10%, 25%, or even more.

Long and Short Lots.—Having determined a market value of land, the next problem is the application of that value to lots of irregular size and shape, corner lots, and groups of lots. A market value of dollars per front foot refers to property of average depth, depending on the manner in which the city is platted, and it is frequently necessary to apply this value to a lot either shorter or longer than the average. Several tables have been compiled by different authorities showing the percentage of the total value of lots 100 ft. in depth which is represented by a lot of any other depth, either greater or smaller. A number of well-known rules have been tabulated and are submitted herewith in comparative form. The Hoffman rule appeared prior to 1870, and was based on the assumption that the front half of a 100-ft. lot was worth two-thirds of the total value of the lot. The 4-3-2-1 rule, which is as old, assumed that the front 25 ft. of a 100-ft. lot represented 40% of the total value, the second 25 ft., 30% of the value, the third 25 ft., 20%, and the rear 25 ft., 10 per cent. The Hoffman-Neill rule is a modification of the Hoffman rule, and the Newark rule was developed by the assessing body in the City of Newark. The Somers rule is the work of Mr. Somers, who was long associated with assessment work in New York City. Mr. Pleydell's rule is based on extensive studies in New York City; and the Lindsay-Bernard rule was developed from a mass of data gathered in Baltimore. The Milwaukee rule has been developed during a period of years by Mr. J. H. Leenhouts, connected with the Milwaukee assessing body, adjustments having been made from time to time as additional data warranted. In Milwaukee and Newark separate rules are used for business and residence property. The Davies rule is the work of Mr. William E. Davies, of New York City, and was adopted by him after a study of more than 10 000 sales. Most of the rules are based on a 100-ft. depth of lot, but the Lindsay-Bernard and Pleydell percentages are based on a 150-ft. lot. By a simple computation it is possible to reduce these percentages to the 100-ft. lot basis, as, for example, to find what ratio a 50-ft. lot bears to a 100-ft. lot, according to the Lindsay-Bernard rule, enter their table and divide the percentage for a 50-ft. lot by the percentage for a 100-ft. lot. This operation gives $58 \div 88 = 66$ per cent. This

computation has been made for all values in the rules which are not based on a 100-ft. lot, and recorded in Table 2 for purposes of comparison. Columns (1) to (11) have been platted on Fig. 2. All the rules are not shown here in their complete form, as some of them give a percentage for every foot of variation in depth instead of every 5 ft., and, also, some of them have the percentages worked out to three decimal places instead of two. Percentages for depths of lots other than those shown in the tables may be determined by interpolation, and the application of percentages worked out to one-tenth of 1% is a needless refinement, as market values cannot be determined with any such degree of accuracy.

TABLE 2.—Comparison of Rules for Long and Short Lots.

Depth of lot, in feet.	(1) Hoffman.	(2) 4 — 3 — 2 — 1.	(3) Hoffman-Neill.	(4) Newark, business.	(5) Newark, residence.	(6) Milwaukee, business.	(7) Milwaukee, residence; on 100-ft. basis.	(8) Davies.	(9) Somers.	(10) Lindsay-Bernard; on 100-ft basis.	(11) Pleydell; on 100-ft. basis.	(12) Lindsay-Bernard.	(13) Pleydell.	(14) Milwaukee, residence.
5	....	....	17	......	......	17	7	13	14	10	....	9	......	6
10	....	....	26	25	16	28	14	22	25	17	....	15	......	12
15	....	....	33	......	......	37	19	29	33	24	....	21	......	17
20	....	....	39	41	30	44	26	36	41	31	....	27	......	23
25	38	40	44	......	......	49	32	42	48	37	45	33	38	28
30	....	....	49	54	44	54	37	47	54	43	....	38	......	33
35	....	....	54	......	......	59	42	52	59	50	....	44	......	37
40	....	....	58	64	55	63	48	57	64	56	....	49	......	42
45	....	....	63	......	......	67	53	61	68	61	....	54	......	47
50	67	70	67	72	65	70	58	65	72	66	68	58	57	51
55	....	....	71	......	......	74	63	69	76	72	....	63	......	55
60	....	....	74	80	74	77	67	73	80	76	....	67	......	59
65	....	....	78	......	......	80	72	77	83	81	....	71	......	63
70	....	....	81	86	83	84	76	81	86	84	....	74	......	67
75	88	90	84	......	......	87	81	84	88	87	87	77	73	71
80	....	....	88	91	91	90	85	88	91	91	....	80	......	75
85	....	....	91	......	......	93	89	91	93	93	....	82	......	78
90	....	....	94	96	96	95	93	94	96	95	....	84	......	82
95	....	....	97	......	......	98	97	97	98	98	....	86	......	85
100	100	100	100	100	100	100	100	100	100	100	100	88	84	88
105	....	....	......	......	......	102	104	103	102	102	....	90	......	92
110	....	....	......	104	104	103	108	106	104	103	....	91	......	95
115	....	....	......	......	......	105	111	109	106	105	....	92	......	98
120	....	....	......	108	108	107	114	111	108	107	....	94	......	100
125	....	....	109	......	......	109	116	114	109	108	112	95	94	102
130	....	....	......	112	112	110	117	116	110	109	....	96	......	103
135	....	...	......	......	......	112	119	119	112	110	....	97	......	105
140	....	....	......	116	116	113	121	121	113	111	....	98	......	107
145	....	....	......	......	......	114	123	124	114	113	....	99	......	108
150	....	....	117	120	120	115	124	126	115	114	119	100	100	109
155	....	....	......	......	......	116	126	129	116	....	....	......	......	111
160	....	....	......	124	124	117	127	131	117	....	....	......	......	112
165	....	....	......	......	......	118	128	134	118	....	....	......	......	113
170	....	....	......	127	127	118	130	136	118	....	....	......	......	114
175	....	....	124	......	......	119	131	139	119	....	....	......	......	115
180	....	....	......	129	129	120	132	141	120	....	....	......	......	116
185	....	....	......	......	......	120	....	143	120	....	....	......	......	117
190	....	....	......	131	131	121	....	145	121	....	....	......	......	118
195	....	....	......	......	......	122	....	147	122	....	....	......	......	118
200	....	....	130	133	133	122	135	149	122	....	....	......	......	119

Of these rules, the Lindsay-Bernard, Milwaukee, Davies, Newark, Pleydell, and Somers are based on actual investigations, and not on assumptions. Of these, the first three appear to represent the most careful study. The Milwaukee authorities have made an excellent point in distinguishing between residence and business property. It is entirely logical that such a difference should exist, and it is easy to understand that in business property a larger proportion of the value would lie in the front portion of the lot, as indicated by the curves. It should be noted that a curve drawn midway between the Milwaukee business and residence curves, and therefore representing average conditions, would coincide more closely with the results of other investigators. The Davies rule is probably more representative of conditions in the large Eastern cities, as it is based largely on data obtained in New York City. It is practically impossible for every appraiser to collect data and formulate his own rule, and it is necessary for him to use the work of others, choosing that which in his judgment appears most reasonable and is supported by the most thorough investigation. It should be noted here that not in every case does a short lot have a greater value per square foot than a lot of standard length. In a tenement district, for instance, a lot too short to be used for tenement purposes would have a lesser value per square foot than a lot of standard length. Such cases are infrequent, however, as such lots are eventually combined with other property, in order that their highest utilization may be attained.

The use of a rule for long and short lots enables one to place a value on a few square feet in any part of a lot, having given the distance to the street. For example, to find the value of a lot 20 ft. deep and 60 ft. from the street, just subtract the value of a 60-ft. lot from that of an 80-ft. lot, as determined from the rule. The application of this procedure to L-shaped lots and lots which have no frontage may be readily seen. Where the sides of a lot are of different lengths they may be averaged, that is, if one side of a lot is 60 ft. long and the other side 80 ft. long, obtain the value of a 70-ft. rectangular lot according to the rule used. Where lots are irregular in shape they may be divided into small squares, and the values of the squares may be determined and summed.

Value of Corner Lots.—A more difficult problem than long and short lots is presented in the determination of corner lot values. Vari-

ous formulas have been devised for computing the value of corner lots, having given the value per front foot of an inside lot on both the main and side streets. It would seem that any formula or rule for determining the corner influence would be inadequate, because the corner lot value is affected by a number of factors, among which are the value of land, the relation of land values on the main street to those on the side street, the width and depth of lots, the height of buildings, the kind of occupancy, and other conditions. In making a city assessment, it is almost necessary to use a rule, on account of the great amount of work to be done; and most of the authorities mentioned have devised a procedure for this purpose. It is felt that none of the rules is adequate, although some of them may be applicable in a majority of cases.

Mr. A. C. Pleydell's rule is to consider the corner as an inside lot on the main street, add 15% and also add 50% of its value as an inside lot on the side street and extended according to the Newark rule. This method is the result of careful study by Mr. Pleydell, but it is understood that he is not prepared to justify it entirely, and offers it more in the nature of a suggestion. A method of determining corner lot values has been worked out by Mr. W. A. Somers, of the Manufacturers Appraisal Company, of Cleveland, the basis of which is not made public. He states that the corner influence in all property generally extends 100 ft. each way from the corner, and he has compiled tables which indicate for any combination of unit values on the main and side streets the value of each 10-ft. square. The values of these squares may be summed to obtain the value of a lot of any shape or size within the 100-ft. corner square. It would seem that any rule applied with such mathematical precision is altogether too inflexible to meet the great variety of conditions which obtain with respect to corner lots.

The City of Milwaukee uses a rule which has been developed by Mr. J. H. Leenhouts, Chief Clerk for 18 years in the city Tax Commissioner's Office, with the co-operation of the Milwaukee Real Estate Board. It is stated as follows: For residence property where all street improvements are made, add 25% of the value of the main street frontage on a width of 30 ft. for corner influence. For business property add the value per front foot (computed as an inside lot and extended according to the Milwaukee rule for business property) of the main and

side streets, divide by two, and take 60% of the result, which determines the value per front foot to be added for corner influence on a width of 40 ft. on the main street. In all cases this method is subject to local conditions and the judgment of the appraiser. As regards business lots, the application of this formula nearly always adds less than 50% to the value of a corner property, as compared with an inside lot, and it is considered that the tendency is to give results which are too low. The Lindsay-Bernard corner lot rule consists in fixing the value of the property as an inside lot on both the main and side streets and adding the two. The sum is taken as the minimum value of the corner, and to it are added all minor factors of value which suggest themselves to an intelligent appraiser. This rule has been tested by the authors in the case of more than 400 sales and rentals, with good results. Although it yields much higher values than the other rules, it is considered to be the most satisfactory of them all.

Many real estate men simply add to a corner lot 50% of the value of an inside lot. Mr. E. H. Gilbert advocates the following procedure for New York City, where nearly all lots have a frontage of 25 ft. To the lot adjoining a corner lot add 10% of the value of an inside lot. To the corner lot add 60% of the value of the lot adjoining the corner. It is probable that a more reliable procedure is represented by a set of rules used by Mr. George C. Olcott, a real estate appraiser of Chicago. In some respects his method is not as definitely outlined as in some of the other rules mentioned, and consequently his system is more flexible.

Mr. Olcott's system of corner valuation is as follows:

"The value per front foot for inside lots of an average depth in any block having been ascertained, the value of the corner lot per front foot may be arrived at with approximate accuracy by the adoption of the following rules:

"On Residence Streets.—To the value per foot on the frontage street, add one-quarter of the value per foot of the side street.

"Thus, if the value of the street on which a lot faces has been placed at $100 per front foot for that block, and the value of the lots on the side street at $80 per front foot, the value of the corner may be safely called $120 per front foot.

"In estimating the value of corner lots on any street, 50 ft. is regarded as coming under the corner influence. If the 50 ft. is divided up into two holdings, the corner value with few exceptions applies only to the immediate corner lot.

"On Residence Streets in Transition to Business Streets.—To the value per foot on the frontage street add one-half of the value per foot of the side street.

"On Business Streets Outside Down-town Center.—To the value per foot on the frontage street add the full value per foot of the side street. The increase, however, should not be less than 25% of the high value unit.

"If a transfer corner, where the intersecting car lines run at right angles for some distance and do not parallel each other partly or wholly, a fair basis to start on is the full value per foot of the values placed on the four converging blocks added together. To this add such a percentage as may be suggested by length of distance traveled and population of tributary territory thereto of said lines. Local conditions, such as license district limits, population immediately around said corner, nearness of factory, church, or school, affect corner values favorably or otherwise.

"Perhaps as accurate results as by any method may be arrived at by estimating the value of all the corners on a given business street, in order to find the relative value of the particular one desired. Select the best corner on the street, then the next, and the next, to the least valuable corner. Get all the data possible, of sales and asking prices. Start from the ascertained facts and increase or decrease proportionately the value of the corners as they have been selected as better or less desirable than the ones from which the data have given a starting point.

"In Factory Districts.—To the value per square foot on the main frontage street, add three-eighths of the value per square foot placed upon the side street. Use square-foot values only in factory districts.

"Down-town Corners.—No rule can be applied successfully to down-town corner values. Each must be determined by itself on a square-foot basis, taking into consideration location, conditions, size, shape, and even occupancy. In large department stores, one square foot is practically as good as another, whether corner or inside, when considered as a whole."

As in the case of rules for long and short lots, every appraiser is not able to gather a great number of data, and must be guided to a certain extent by the work of those who have made extensive investigations. The results of work on corner lot values, however, are somewhat meager and contradictory, and it is advisable to study each individual problem and check, in as many ways as possible, the results obtained by the application of some rule or percentage. A corner lot is more valuable than an inside lot by reason of the increased accessibility, the better possibilities of utilization, and the additional light and air. Increased accessibility and availability include all such

factors as greater facility of entrance to the property, added show-window and advertising space, increased amount of traffic at a corner, and the greater possibilities in designing buildings. If those advantages could be appraised and their value added to that of an inside lot, a check on corner lot values would be obtained.

In the case of business property, where all the factors mentioned must be considered, such a course is scarcely feasible; but it is practicable in simpler cases, such as occur in factory districts, where light and air are the only advantages to be gained by corner locations. The value of the advantage may be measured in such an instance by estimating how much vacant frontage would be required adjoining an inside lot in order to give it as much light and ventilation as the corner lot, and multiplying that frontage by the unit land value. If land has a market value of $400 per front foot and it is estimated that 22 ft. of vacant space would be required to give an inside lot as much light and air as the corner lot, then the sum to be added for this advantage would be 22×400, or $8 800. The estimated additional frontage, of course, should not exceed the width of the side street. This method is modified by a number of factors, such as the height of buildings, the shape and size of the lot under consideration, and the possible design of improvements as regards artificial lighting or the disposition of courts and light-wells.

As a rule, corner influence does not extend across ownership lines along the main street, and property adjoining a corner lot on the main street is of little higher value than any other inside frontage. Only in so far as it is located close enough to the corner to benefit by the increased street traffic there does it have any increased value whatever. Along the side street the corner influence generally extends beyond the corner lot, the value of frontage grading down regularly from the main street corner until the normal market value on the side street is reached. As light cannot be utilized more than 40 ft. from the lot line, the added value due to it should not attach to property more than that distance from the corner. Moreover, if the corner lot is narrow, the light advantage cannot be completely utilized, and is of less value. Corner values in residence property are of much less importance than in business property. In a district where each building is on a fair sized lot with plenty of space around it, the corner has practically no additional value beyond that which is due to the additional street im-

provements; but, in more crowded sections, where there are flats and apartment houses, the corner lot may be worth from 25 to 50% more than inside lots.

Many of the large real estate and appraisal offices have their own rules for handling questions of long and short lots and corner lots, and guard them carefully as office secrets. It is hardly possible that their private studies should yield information varying to any great extent from that which has been discussed herein, except in cases where it applies to peculiar local conditions. A number of the most difficult cases in determining land values are encountered in appraising corner lots. Every corner lot presents a different problem, and, after general rules have been applied, each case should be studied with regard to its peculiar features.

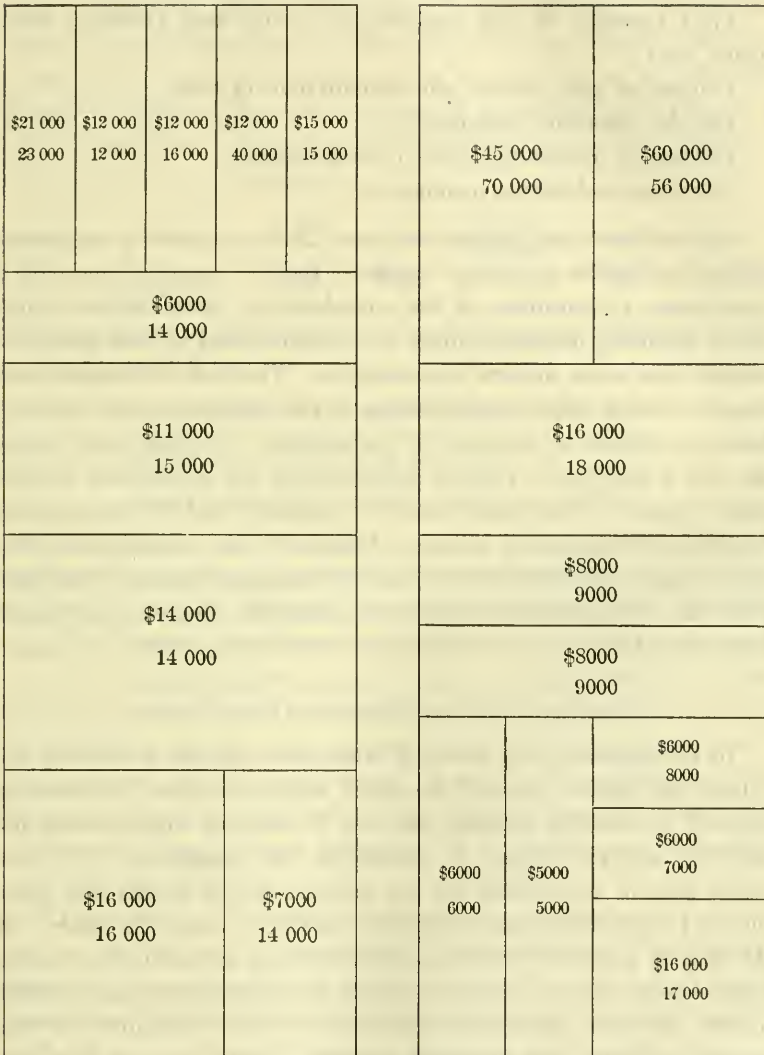
Plottage.—In certain classes of property, where several lots or blocks, or an unusually large frontage, are held under one ownership, a tract of land may have an additional value by reason of its being thus held. Where such conditions prevail, the tract is said to have plottage, and, where the land is more valuable by reason of such conditions, to have a plottage value. Although a piece of land may have an unusually large area, it does not have plottage value unless it can be occupied by some utility which requires an extra large site. If a tract of six or eight adjoining lots is available only for dwellings it will have to be broken up into single lots in order to be utilized, and consequently has no additional value; but, if it were owned by a traction company, and used for a car-barn site in a district where tracts of equal size were not readily available, it would have a plottage value. When a market value for such a tract has been determined, it is customary to add a percentage to cover the plottage value, and 10 and 15% are commonly used. Plottage value exists by reason of the fact that it is necessary to expend amounts in excess of market values in order to gather several adjoining pieces of land under one ownership, and some measure of the amount to be added for this value can be ascertained by estimating what additional expense would be incurred in gaining control of several adjoining properties held under separate ownership. In acquiring land, under such circumstances, it is not always possible to condemn, but it is possible to obtain options and get the proposition lined up so that the owner of one parcel cannot demand a prohibitive sum after money has been invested in several surrounding tracts. Even with careful buying,

however, the grantee is generally obliged to pay an exorbitant price for one or two lots in order to close a large deal. Such a transaction, however, is not made unless a considerable portion of the tract can be obtained at a reasonable market value, and though a double price may be paid for some pieces, the percentage above market value, computed on the entire purchase, is not apt to be excessive.

Fig. 3 is a diagram of a group of lots purchased by a large company for a home office building site, and is a fair example of the manner in which such a property is acquired. Twenty parcels of land were purchased, constituting an entire city block. On each parcel is shown the estimated market value and directly under it the sum paid out for that piece of land. The market value of the entire block was \$302 000 and the total cost of acquiring the twenty parcels was \$384 000. The excess over market value was \$82 000 or 27%, but, nevertheless, the deal represented a very good piece of buying, and the total tract could be said to have a fair plottage value of \$82 000. This instance is unusual, a much more frequent case being where three adjoining lots are worth \$2 400 each and the plottage value for the three together is estimated at \$800. Plottage value may be said to range from 10 to 25% of the market value, the percentage decreasing as the value of property increases, and increasing in proportion to the number of lots or parcels constituting the tract.

Cost of Acquiring Land.

Considered from a different viewpoint, plottage value is simply one of three items which may be called collectively "the cost of acquiring land", as it represents an amount in excess of market value which it is necessary to pay out in order to purchase several adjoining pieces of land. Another item of this group is the cost, in connection with purchasing land, of buying and removing buildings or other improvements which are on the land but are of no value to the purchaser. There are numerous cases in connection with land purchases where large and serviceable structures have been wrecked to make room for a different type of improvement, and, even considering the salvage, the expense involved is often considerable. This cost, of course, is subject to no regular influence, and must be determined under the conditions existing where it is encountered. The third item of the cost of acquiring land is the actual expense in connection with making the purchase, and composes one or more of the following sub-items:



Upper Figures=Market Value
Lower Figures=Purchase Price

Fig. 3.

Expense of searching for and choosing a site;

Salary or commission of men engaged in buying land;

Field expenses of men engaged in buying land (railway, hotel, livery, etc.);

Expense of legal services and examinations of title;

Fees for recording instruments;

Expense of registering title in land courts;

Surveying and setting monuments.

In most cases the purchase is placed in the hands of a real estate broker, and his fee is the only expense. Brokers generally charge as a commission a percentage of the consideration, which varies in different localities, depending often on the rules fixed by real estate exchanges and other brokers' organizations. The cost of abstracts and examinations of title varies according to the condition of the title, and bears no relation to the value of the property. In some cases, where the title is involved, it requires litigation and the expenditure of large sums to clear it. Such cases cannot be estimated, and the expense must be obtained from actual records. Ordinarily, the expenditures mentioned under the third item of the cost of acquiring land vary from 2 to 8% of the market value of the property, the lower percentage being more likely to occur when land reaches high values.

Different Theories Regarding Land Values.

In the valuation of a parcel of land, there may be determined two values: the market value and the cost to acquire the latter, representing the cost of obtaining plottage, the cost of removing improvements not required, and the expense in connection with purchasing. The two values may be determined for two periods, that is, at the date when the land is purchased and at the date when the valuation is made. At the date of purchase both the values represent an estimate of actual expenditures. At the date of valuation the market value may be much higher, due to an increase in values; and the cost to acquire will be a speculative value, also increased over the original cost, as it is to a large extent proportional to the market value.

Assume the history of a property to be as follows: Four lots having a market value of $3 000 each were purchased by a company for the sum of $14 900; buildings of no value to the company were purchased

and removed at a net cost of $4 700; and the expense of purchasing the property was $500. The total expenditure was $20 100, of which $12 000 represents market values and $8 100 the cost to acquire. Assume, further, that 20 years later the lots have a market value of $6 000 each; that a careful estimate of the amount to be added for plottage is $5 000; that the net cost of removing the buildings is placed at $11 000; and the expense of purchasing at $700. What is the value of the tract of land?

Date.	Property.	Market value.	Plottage.	Net cost of removing buildings.	Expense.	Total.
1896	4 lots............	$12 000	$2 900	$4 700	$500	$20 100
1916	Same property..	24 000	5 000	11 000	700	40 700

The investment cost $20 100. The capital charge (allowing for the increase in land value) is

$$\$24\,000 + \$2\,900 + \$4\,700 + \$500 = \$32\,100,$$

or, if the increase in plottage is also included,

$$\$24\,000 + \$5\,000 + \$4\,700 + \$500 = \$34\,200.$$

The sale price to another company would be $24 000 + $5 000, or $29 000, but the replacement value would be $40 700. The foregoing is an extreme case, and is given to show the variation in valuation results, worked out under different theories or for different purposes. In public utility regulation cases, there is a strong tendency, in land valuation at the present time, to use the market value as of date of valuation, and add the cost to acquire as of date of purchase. This is in conformity with a theory which allows a utility to capitalize the increment in land values, but does not consider that it is entitled to an increment, more or less speculative, to expenditures in connection with land purchases.

Values Based on Special Utilization.—In frequent cases a tract of land is held to have an exceptional value because it is particularly adapted to the purposes of the utility by which it is occupied. A steam-power plant may be on the bank of a river where plenty of water is available for heating and condensing purposes, and the conditions may be such that no other site with equal facilities is to be had. The position often taken in such cases is that the location has a peculiar advantage for steam plant purposes, which it would not necessarily have for the purposes of a wholesale house, a railroad yard, or some

other utility; and, as a similar location cannot be obtained, it has a value in excess of the market value of adjoining lands. This additional value may be based on the extra cost of providing a tunnel from some other location to the river, or on the saving effected by the existing water supply over a well supply. A further step in this direction is to give land a value based on its highest utilization, even though such utilization has not been accomplished. A notable instance is the case of certain islands in the Upper Mississippi River which were taken for public use. The jury assessed their value as waste land, and, for any except boom purposes, at $300; but, in view of their adaptability for the formation of a boom across the river, at more than $9 000. The Court found the owner entitled to the larger sum, although the islands were not at the time, in fact, used for boom purposes, but were capable of such use. Instances of this kind are mostly encountered in land damage and land condemnation cases, and are based on the wording of the laws governing such cases, which state in brief that when a man's property is taken from him he shall be recompensed to the extent of its full value for its most valuable use. High values, in such instances as the steam plant location, however, are based on the theory of the cost of replacement of the property. In the majority of these situations, neither was the actual cost of the land excessive, nor could the land be sold to another utility for a high figure; and extra value is claimed simply because, if the power company did not own the site, it would require great expenditure to obtain one which would be as suitable.

The method of handling such cases depends on the theory under which the valuation is undertaken. If the basis of the work is "what would it cost us to replace this land if we did not own it", or "what expenditures would be entailed if we could not obtain it", it is easy to justify extreme values. Consideration should be given, however, to factors which sometimes modify these values. A small rocky island in a river may be said to be very valuable to a water-power company as an anchorage for a dam, but, in valuing the entire property of the company, the fact that a high value has been placed on a bit of waste land increases the theoretical cost of developing the water-power, and, when the value of water-power rights is computed, they will be found to have a lesser value to exactly the extent that the theoretical cost of development has been increased by placing a high value on the

island. Such an island may save many dollars to a railroad company as a footing for a bridge pier, but, if it has been necessary to change the grade or alignment of the road in order to cross the river at that point, the saving may be greatly reduced. Even though the island were directly in the path of the railroad line and could be utilized for a bridge foundation without any extra expenditure to make it available for that purpose, it is questionable whether the land would have any but a nominal value. The island is only a natural feature of the territory crossed by the railroad, and to claim a high value for it is akin to placing a higher value on railroad right of way in a level district than in a hilly one, where land has the same value for farm purposes, but where earthwork and curves make railroad construction and operation more expensive. It is evident that appraising land on the basis of its value for certain uses may be carried to absurdities.

To return to the case of the steam-power plant, previously cited: There are in every large community utilities which require facilities for coal and water supplies, and, if locations with such facilities are limited, the competition is bound to develop a stiff market value for land of that class. On the contrary, in situations where the plant is on land which, if not used for power-plant purposes, would be occupied by a utility which would not take advantage of the special facilities offered, the market value of the land should be based on that class of utilization. Sometimes a utility, in buying a piece of land particularly suited to its purposes, pays a large sum for it when no other utility is competing for the location, simply because the owner recognizes that the purchaser is especially desirous of obtaining it and holds to a figure above the market value. The utility may want the land because it has special facilities for coal and water supplies or because it adjoins land already owned, but in either case it is simply a circumstance that confronts the purchaser, and the market value of the land is not increased thereby. Generally, the sum paid for a piece of land having a special value to the purchaser is not excessive, due to the fact that the seller frequently considers the value from the viewpoint of his own utilization of it, and does not ask himself "what is it worth to the purchaser". A railroad company requiring earth for a large fill may acquire a particularly suitable piece of land at the market value, the seller having in mind only its value as farm land and not considering that the purchaser wants it for filling

material and would have a long haul if the material were obtained elsewhere. Under such conditions, the purpose for which property is wanted is concealed, and, where the identity of the purchaser would suggest it, the transfer is made through a third party.

In concluding this phase of land values it may be said that the cost of replacement as applied to land may lead to extreme results, and furthermore, it is a theory which is considered by many authorities to be unsound for most appraisal purposes. If a market value is to be determined for land which has special advantages for certain utilizations, it should not be abnormally high unless there is competition for the location based on its peculiar facilities.

Value of Railroad Land.—The valuation of railroad lands is a problem which has confronted appraisers in recent years. Such valuations are generally made by employing men familiar with land values, and they gather sales and other data regarding the value of land along the railroad right of way, and use the information collected, supplemented with personal opinions, assistance from real estate dealers, and notes from the company's records, to fix the values. Railroad lands are so extensive, and include so many grades of property, that an appraiser is not warranted in going into details to the extent that is customary in making ordinary land valuations. Not only would it be too laborious a procedure under most circumstances, but there would be little net gain in the accuracy of results. By using a rougher method, any individual tract of railroad land may be given a market value that is in error, but, if all inaccuracies are compensating, the net error throughout a State, or even in one city, is a very small percentage of the total value.

The method of using tax assessments which has been outlined heretofore is particularly applicable to the valuation of railroad lands. Maps are first provided showing the railroad lands and also the adjoining property for several blocks on each side of the right of way and terminal grounds. Owing to the nature of railroad lands, the units, such as lot values and front foot values, cannot be readily applied, and it is necessary to use the value per square foot. In order to compare and apply the assessments on adjoining lands, they must be reduced to the square-foot unit, if they do not exist in that form in the public records. The assessments are recorded on the map, and the right of way is then inspected in the field in order to determine its relative value

as compared with adjoining lands. In the light of the inspection and the data recorded on the maps, the railroad lands are given an assessed value which is subsequently converted to market value by applying the ratio which has been found to exist in that particular district between market values and assessment values. The market value determined for any given piece of railroad land may be slightly incorrect, but the net result for a city is accurate, as no cumulative errors are introduced. This method may be used in either city or country districts, and is very convenient where good sales are scarce, which is generally the case.

Cost of Acquiring Railroad Land.—In acquiring railroad right of way, many expenditures are incurred in addition to paying the market value of the land purchased. Among the more important may be listed the following:

1.—Wages and commissions of men engaged in purchasing land;
2.—Field expenses, traveling, livery, board, etc., of men engaged in purchasing land;
3.—Printing and advertising, notices, etc.;
4.—Abstracts and examinations of title;
5.—Fees for filing and recording documents, etc.;
6.—Condemnation and legal expenses;
7.—Purchase of buildings, orchards, crops, etc., on land required for railroad purposes;
8.—Damages to adjoining property;
9.—In addition there are the amounts paid out which represent no value received or damage inflicted, but merely the sums which it is possible for land owners to extort from a railroad company under the conditions which prevail in buying railroad lands.

The first six items are small, and range from 4 to 12% of the total amount paid for land. The smaller percentage obtains in the case of a large railroad having a land department and a purchasing organization, and the larger percentages are found in the case of small electric lines acquiring only a few miles of right of way, and using only a temporary organization for the purpose. These items are of minor importance, however, and the cost of acquiring railroad land is determined chiefly by the magnitude of Items 7, 8, and 9. These three items are not

governed by any established laws or ratios, but are controlled to a certain extent by the following factors, and it is impossible to determine the extent of any one influence separately:

1.—Value of Land.—As the value of land increases, the proportional cost to acquire decreases. In buying cheap lands, the railroad companies do not make the effort in purchasing that is made in cities, where the investment is larger, nor are they so likely to resort to condemnation, for it is sometimes cheaper to pay five or ten times the market value of poor lands than to undertake the expense of condemnation.

2.—Ownership.—The class of ownership and the area of land under single ownerships is a factor. In some of the lumber States there are thousands of acres of cut-over timber lands held by single lumber companies, and it is possible to obtain large portions of a right of way at reasonable figures by dealing with only a few such land-holders.

3.—The extent to which a community is built up obviously affects the matter of damages in both city and country lands. In undeveloped territory, it is possible to buy land cheaper by reason of the fact that land-holders are desirous of obtaining railroad facilities. A new line through districts already well supplied with railroads, however, obtains no such favors.

4.—The direction of a railroad line has some effect on the extent of damages. A line running diagonally across the country cuts all farms into triangular pieces, but a right of way which parallels the section lines, preserves the shape of fields and causes less damage.

5.—One of the chief factors in the cost of acquiring railroad lands is the skill of the company's buyers. There are instances where right of way has cost a railroad company 50% more than it should have, owing to poor buying.

There are many other influences which are of a minor or local nature.

The only way to determine the cost to acquire a given strip of right of way is to learn from the company's records what was actually paid out in acquiring it and deduct from that sum the estimated market value of the land. Investigations of this kind show that the cost under

different conditions varies tremendously, ranging all the way from 5 to 600% of the market value. If it is necessary to make an estimate of this cost and no records are available, a study should be made of the results of purchases of railroad lands in near-by territory, under similar conditions to those affecting the right of way under consideration. If such a guide is not to be had, an estimate is largely guesswork. Although the variation is great, the average of the cost to acquire land for railroad purposes in a number of instances has been from 50 to 100% of the market value in cities and from 200 to 300% of the market value in country districts.

Cost of Land Appraisals.

The cost of making appraisals of property generally runs from one to two-tenths of 1%, and, as a rule, the work done on the land should not be more expensive than that on other classes of property in an inventory. Real estate men charge fees for appraising land which range as high as one-quarter of 1% for city property and one-half of 1% for suburban property. The cost of valuing the land of a utility should increase according to the number of scattered parcels to be handled, and should decrease in proportion to the increase in the value of lands to be appraised. It may easily require less effort to appraise a single parcel of land worth several hundred thousand dollars than to place a value on several parcels, the aggregate value of which is not nearly as great.

AMERICAN SOCIETY OF CIVIL ENGINEERS
INSTITUTED 1852

PAPERS AND DISCUSSIONS

SUGGESTED CHANGES AND EXTENSION OF THE UNITED STATES WEATHER BUREAU SERVICE IN CALIFORNIA

REPORT OF A COMMITTEE OF THE SOUTHERN CALIFORNIA ASSOCIATION OF MEMBERS.

Discussion.*

By J. B. LIPPINCOTT, M. AM. SOC. C. E.

J. B. LIPPINCOTT,† M. AM. SOC. C. E. (by letter).‡—The writer wishes to express his appreciation of this paper concerning the work of the U. S. Weather Bureau in California. This subject is of such interest to the hydraulic engineers of the West that this Committee (consisting of Mr. Binckley and Mr. Lee), representing the Southern California Association of Members of the American Society of Civil Engineers, was appointed for the purpose of reviewing this work. The report of the Committee was presented at a regular meeting of the Association, an evening was given to its discussion, a resolution of commendation was passed, and its publication by the Society was requested. Mr. Lippincott.

The work of the Weather Bureau and its predecessor, the United States Signal Service, in arid America has been of great value to engineers engaged in the study of the water problems of the West. The writer is especially indebted to the Service for much useful information. It is relatively an easy matter to maintain rain gauges, and an exceedingly difficult one to maintain stream gauging stations throughout a term of years. For this reason the engineers have had

* Discussion of the paper by George S. Binckley, M. Am. Soc. C. E., and Charles H. Lee, Assoc. M. Am. Soc. C. E., continued from March, 1916, *Proceedings*.

† Los Angeles, Cal.

‡ Received by the Secretary, October 16th, 1916.

Mr. Lippincott. to rely largely on records of the Weather Bureau and Signal Service as a basis of their study of the available water supply for irrigation and water power.

There is a constant tendency for the older bureaus of the Federal Government to maintain themselves in the City of Washington without adequate field inspection, particularly of the far western country. It is not efficient, and in fact usually is very unintelligent for one to endeavor to direct, year after year, from a desk in the Capital, field operations on the far side of a continent. This lack of proper executive has not alone characterized the Weather Bureau for a number of years past, but many other departments of the Government. This habit was broken away from vigorously first by the Geological Survey, and then by the Forest Service and the Reclamation Service.

The Engineering Profession should use its influence in obtaining, if possible by co-operation with the Weather Bureau, an expansion and improvement of its work along lines that will be of greater value to this Profession.

In California there are two great hydrographic features: First, the Pacific Ocean with 850 miles of coast line lying to the west, from which all moisture is derived; and, second, the great Sierra Nevadas and Coast Ranges of mountains that are the condensers which collect the vapor from the clouds and put it into the streams. The rainfall in the valleys of California is small, ranging from 5 to 10 in. in the Great Central Valley, and from 10 to 15 in. along the coastal plains of Southern California. The desert rainfall to the east of the Sierra is less than 5 in. annually. The precipitation on the mountain crests is enormously greater, the increase in depth of annual rainfall being at the rate of approximately 0.6 in. for each 100 ft. rise in elevation on the western slopes of the ranges up to some unknown limit of from 6 000 to 8 000 ft. The water, both for the irrigation supply and the development of power, comes from these high mountains, yet in California there are eleven regularly established Weather Bureau stations, all in the valleys and none in the higher mountains, the one possible exception being on Mt. Tamalpais, which is a branch of the San Francisco office on a foot-hill near that city.

Apparently, the original purpose of the Weather Bureau was to be of primary aid to shipping, which is of first importance. Seven of the eleven official weather stations in California are on the sea coast, and the others are in low valleys. In California there is great variation in the rainfall within short distances. For instance, at Fresno, in the San Joaquin Valley, the yearly rainfall is about 7 in., and 30 or 40 miles away the precipitation on the Sierra Nevadas is from 50 to 60 in., yet there are three official stations in the Central Valley and none on this main range. In a horticultural State which relies largely on irrigation for its success, and is greatly interested in flood

problems and inland waterways, this would appear to be a condition to correct. The same argument applies in Southern California. If it is impossible to discontinue any one of the seven coast stations, it is essential that additional regular stations be established in the high mountain drainage basins. Apparently, the cost of maintaining one of the city offices would be enough to support two in a forest reserve where a cabin could be built and the records kept in an open field. Mr. Lippincott.

There are some voluntary observers in these mountain regions, but they are rarely at the higher elevations, or at points where maximum precipitation occurs. These voluntary observations are usually fragmentary, and are not an adequate substitute for a regular station.

Both off the west coast of Europe and the west coast of America the warm currents or streams of the ocean have a profound effect on the climatic conditions of the regions on which they impinge. It is quite possible that there is some variation or swing in these ocean streams from year to year. Navigators talk of open and closed winters off the coast of Northern Alaska, and there have been remarkable groups of wet and dry years in California. Storms originate on and travel easterly from the Pacific Ocean across the continent. So far as the writer knows, nothing has been done, in a broad and systematic way, to study the fluctuation in temperatures of the ocean water off the Pacific Coast. There are light-houses at short intervals from San Diego to Seattle, and others farther north. It would be a simple matter, not accompanied by serious expense, for the Weather Bureau to arrange with the Light-house Service for the taking of daily temperatures of the water of the ocean, with a view of determining the possible relations between changes of water temperatures and cycles of wet and dry years. There may be no such relation, but it is a physical condition that might be studied to great advantage. The fishing industry of the Pacific Coast is growing to prime importance, and some believe that the schools of fish in their migrations are influenced by the ocean temperatures and that the season's catch is thus governed.

It is respectfully submitted that the work of the Weather Bureau could be substantially improved, also, at the localities where regular stations are now established. It is recognized by engineers, and also by the old Signal Service, that precipitation records should be taken on the level places rather than on pinnacles or near obstructions. The U. S. Weather Bureau has published a record of the rainfall in San Francisco extending back to 1849. This is a composite of observations made successively at six different stations. In 1892 the station was moved to the roof of the Mills Building. There is available a rainfall record, made by Mr. John Pettee, extending back to 1865-66. Although it is said that the gauge observed by Mr. Pettee was moved to different parts of the city several times, it is believed that it was always estab-

Mr. Lippincott. lished near the ground, as distinctive from the roof of a building. For the 27 years prior to 1892 the Pettee record shows a reasonably close relation to that of the Weather Bureau, being an average of 97.2% of it. Subsequent to this date (when the Weather Bureau station was moved to the roof of the eleven-story Mills Building) there was a decided difference in the ratio of the two records. For the period, 1892-93 to 1900-01, the Pettee* record was 134.4% of the Weather Bureau record. This may not be taken as conclusive of the ratio of records maintained on the roofs of high office buildings and those observed near the ground, but it certainly indicates a wide difference in the results. Other examples could be referred to.†

Again, in such a country as California, where a change of a few degrees in temperature in the spring or winter is apt to mean the loss of the fruit crop by freezing, it is not satisfactory to have temperature taken on the roofs of high buildings. Occasionally, we are confronted with reports of frozen fruit, and see some ice in the streets, but we are assured by the official records of the Weather Bureau, taken at its regular station, that the minimum temperatures have been well above freezing. The reverse conditions exist in midsummer. When attention is called to this we are told to apply some factor in correction, but few persons outside the Service know what these factors are. In the writer's opinion, these observations should be taken on the surface of the ground, as it is not satisfactory to say that corrections may be applied to adjust this great mass of observed data to normal conditions.

There are a number of voluntary meteorological observers, mostly in the valleys of California, who, year after year, send in records of rainfall and temperature, whose stations are not inspected, and who are not given personal instructions and encouragement as to the method of their work. Although some of the rain gauges are in good locations, others are not, and may be misleading. A distinction should be made in the records. The writer knew of two old gentlemen who kept a rainfall record for 20 years, from 1882 to 1902, at a place known as Second Gerrote at an elevation of 2 714 ft. Their gauge consisted of three tin cans wired together and set out in the open lot to catch the rainfall. The depth of rain was read in each can with an ordinary foot-rule at the end of each storm, and the three observations were averaged and carefully recorded in a notebook. Such interest in a scientific subject should be encouraged by a visit and personal commendation, and the furnishing of adequate instruments for observation and instruction. The writer has never known of an extended field inspection trip being made by any officer of the Weather Bureau to these voluntary meteorological stations in California, the records from

* *Transactions*, Am. Soc. C. E., Vol. LXI, p. 561.

† Fanning's "Hydraulics", p. 64.

many of which have been continually published for years. It is probably not the lack of interest on the part of the local observers, but rather because of the "system" that is passed down from Washington. Mr. Lippincott.

A great deal of the work done by the men of the Weather Bureau is highly valuable and greatly appreciated. Their prediction of frosts is of greatest importance to the fruit growers of California; their prediction of storms is essential to the mariner. These gentlemen deserve full credit for the thoroughness of their organization, which is believed to be the most extensive meteorological department in the world, yet it is suggested that this service, good as it is, could be substantially improved, from the standpoint of the engineer, without the necessity of large additional outlays.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A STUDY OF THE DEPTH OF ANNUAL EVAPORATION FROM LAKE CONCHOS, MEXICO

Discussion.*

By Messrs. Edwin Duryea, Jr., and H. L. Haehl.†

Edwin Duryea, Jr.,‡ M. Am. Soc. C. E., and H. L. Haehl,‡ Assoc. M. Am. Soc. C. E. (by letter).||—In the paper stress was laid on the uniformity of climatological conditions throughout the Great Plateau which lies between the Western and Eastern Sierra Madres, but it contained no data to prove the claim; and, before taking up the consideration of the discussions, some data will be presented to show such uniformity, as asked for by Mr. Adolph F. Meyer.§ It is believed, also, that these data will be of assistance and value to any one who may have occasion to make hydrographic studies of areas within the Great Plateau. The comparisons will be confined to rainfall, stream flow, and mean temperatures (the only data available), and these, necessarily, are more or less incomplete. However, as rainfall and stream flow may be regarded as resultant elements of climate (as distinguished from such causative elements as humidity, wind, sunshine, etc.), the latter are in a sense included in the former—and similarities in rainfalls, stream flows, and mean temperatures are believed in general to show similarities in climates. Messrs. Duryea and Haehl.

Rainfall.—The rainfall relations to be given are based on the rainfalls of 13 years, 1901 to 1913, for which reasonably complete data of observed monthly rainfalls were secured for fourteen rainfall stations in Southern Texas and New Mexico and for fourteen stations in Northwestern Mexico. Such gaps as existed in the rainfall data were filled

* Discussion of the paper by Edwin Duryea, Jr., M. Am. Soc. C. E., and H. L. Haehl, Assoc. M. Am. Soc. C. E., continued from May, 1916, *Proceedings*.

† Authors' closure.

‡ San Francisco, Cal.

|| Received by the Secretary, October 9th, 1916.

§ *Proceedings*, Am. Soc. C. E., for February, 1916, p. 243.

Messrs. Duryea and Haehl.

TABLE 79.—MEAN, MINIMUM, AND MAXIMUM YEARLY RAINFALLS AT FOURTEEN RAINFALL STATIONS IN SOUTHERN TEXAS AND NEW MEXICO, AND AT FOURTEEN IN NORTHWESTERN MEXICO: FOR THE 13 YEARS, 1901–1913.

Texas and New Mexico.				Mexico.			
Station.	Yearly Rainfalls, in Inches.			Station.	Yearly Rainfalls, in Inches.		
	Mean.	Minimum.	Maximum.		Mean.	Minimum.	Maximum.
San Marcial	9.13	1.17 (1901)	21.79 (1905)	Camargo	6.4	2.4 (1907)	11.8 (1905)
Mesilla Park	9.02	4.02 (1910)	17.09 (1905)	Balleza	18.8	6.0 (1910)	28.3 (1905)
Fort Union	17.24	9.89 (1902)	24.65 (1906)	Guerrero	17.7	5.7 (1910)	25.8 (1905)
Santa Fé	13.83	8.65 (1910)	17.41 (1901)	Parral	15.4	11.6 (1910)	22.7 (1905)
Fort Davis	14.56	8.43 (1910)	23.13 (1905)	Jiminez	11.0	4.0 (1910)	16.4 (1906)
El Paso	9.72	4.03 (1910)	17.80 (1905)	Chihuahua	14.5	5.9 (1901)	21.0 (1906)
Fort Stanton	15.80	9.52 (1903)	22.59 (1905)	Aldama	9.7	7.3 (1909)	13.9 (1905)
Deming	9.31	3.42 (1910)	17.59 (1905)	Ahumada	11.0	3.1 (1903)	20.1 (1911)
Fort Stockton	13.78	4.07 (1910)	20.65 (1905)	Ojinaga	3.2	1.4 (1909)	4.6 (1905)
Fort Clark	20.23	11.62 (1901)	30.94 (1903)	Juarez	9.25	3.8 (1909)	14.8 (1905)
San Antonio	24.94	14.92 (1909)	37.68 (1913)	Ascension	7.1	2.5 (1910)	14.6 (1905)
Fort McIntosh	18.72	4.31 (1901)	36.38 (1903)	Casas Grandes	18.4	4.1 (1910)	35.2 (1905)
Eagle Pass	19.24	8.52 (1910)	30.43 (1913)	La Boquilla	12.0	7.6 (1910)	17.1 (1905)
Roswell	12.91	4.87 (1910)	19.23 (1905)	Pilar de Conchos	15.3	8.0 (1910)	23.9 (1905)
Average	14.90	6.88	24.10	Average	12.18	5.24	19.30

Messrs. Duryea and Haehl.

by careful comparative use of other near-by rainfall records, and the amended yearly rainfalls as used are believed to be reasonably accurate.

A brief summary of the yearly rainfalls at the fourteen rainfall stations in Southern Texas and New Mexico and the fourteen stations in Northwestern Mexico is given in Table 79. The locations of the twenty-eight stations are shown on the isohyetose map, Plate XIII.

Examinations of Table 79 and of the detailed tables from which it is derived show the following general relations between the rainfalls in Northwestern Mexico and those in Southern Texas and New Mexico:

(*a*) During the 13 years, the maximum yearly rainfall at eight of the fourteen Texas and New Mexico stations and at eleven of the fourteen Mexico stations occurred in 1905; and, during the same year, the rainfalls at each of the six remaining stations in Texas and New Mexico and the three remaining stations in Mexico were above the average and generally high, even though not maxima.

(*b*) During the 13 years, the minimum yearly rainfall at eight of the Texas and New Mexico stations and at eight of the Mexico stations occurred in 1910; and, during the same year, the rainfalls at all but one of the six remaining stations in Texas and New Mexico and at all the six remaining stations in Mexico were below the average and generally low, even though not minima.

The comparative regional yearly rainfalls for each of the 13 years are shown in Table 80.

TABLE 80.—Comparative Regional Yearly Rainfalls in Southern Texas and New Mexico, and in Northwestern Mexico, for Each of the 13 Years, 1901-13.

Year.	Mean of Fourteen Stations in Texas and New Mexico.		Mean of Fourteen Stations in Mexico.	
	Inches.	Percentage.	Inches.	Percentage.
1901......	12.8	= 100	9.7	= 75.7
1902......	13.1	= 100	11.8	= 90.1
1903......	15.8	= 100	11.3	= 71.5
1904......	16.4	= 100	13.4	= 81.7
1905......	23.2	= 100	18.5	= 79.7
1906......	17.7	= 100	15.3	= 86.5
1907......	16.2	= 100	11.7	= 72.2
1908......	12.8	= 100	10.2	= 79.8
1909.....	10.4	= 100	10.3	= 99.1
1910......	8.5	= 100	6.1	= 71.8
1911......	16.2	= 100	14.9	= 92.0
1912......	14.0	= 100	11.1	= 79.3
1913......	17.1	= 100	13.8	= 80.7
Average.....	14.90	= 100	12.18	= 81.8

Messrs. Duryea and Haehl. From Table 80, the Mexican regional yearly rainfall varies from about 71% to about 99% of that in Southern Texas and New Mexico, averaging about 82% for the 13-year period, and being between 75 and 85% for 7 of the 13 years.

It should be added that, not only do the yearly rainfalls of the two regions resemble each other closely, but that the distributions of the yearly rainfalls among the 12 months also are very similar, there being throughout the two regions a distinct rainy season of about 4 months (June to September, inclusive), during which about three-quarters of the total rainfall of the year occurs.

Also, even such a very unusual vagary as the heavy snowfall (about 6 in.) which occurred at and south of La Boquilla, Mexico, in the latter part of January, 1915, occurred simultaneously at and north of El Paso, Tex.

A more logical comparison of the regional rainfalls of the two areas was made, as follows:

At each of the fourteen Texas and New Mexico stations, each year's rainfall was expressed as a percentage of the mean yearly rainfall at that station for the 13 years; and, for each of the 13 years, a mean was taken of the fourteen values of Texas and New Mexico percentages, to show the general relation throughout Southern Texas and New Mexico of each year's rainfall to the mean rainfall. The yearly rainfalls at each of the fourteen stations in Mexico were treated similarly for each of the same 13 years, and the resulting regional rainfall relations were derived, as shown in Table 81.

In Table 81 the percentage rainfall relations varied from 100% only by from — 12 to + 22% for the separate years, and the means for the 13 years varied by only 0.4%; and after the end of the third year, the maximum difference in the means was only 2.6 per cent.

As it might be that the 13-year period, 1901-13, was too short or too erratic to give true mean yearly rainfalls, that point was investigated for the fourteen rainfall stations of Southern Texas and New Mexico, with the results shown in Table 82.

In Table 82 the mean yearly rainfall at each of the fourteen stations for the 13 years varied from the mean yearly rainfall for the 47 to 19 years by only from — 5.2 to + 15.8%, with an average variation for the fourteen stations (or for the Southern Texas and New Mexico region) of only + 5.2 per cent.

This concludes the comparison of the rainfalls of the two regions, and is believed to show that they have a marked similarity.

Stream Flow.—Some data are available to show the uniformity of the stream flow characteristics throughout Northwestern Mexico, but none is at hand easily to include Texas and New Mexico in the comparison. The available stream flow data are the measured flows of the Rio Conchos for the 14 years, 1900-1913, at its mouth, near

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TABLE 81.—REGIONAL YEARLY RAINFALLS IN NORTHWESTERN MEXICO FOR EACH OF THE 13 YEARS, 1901-13, EXPRESSED AS PERCENTAGES OF THE MEAN RAINFALL FOR THE 13 YEARS, AND COMPARED WITH SIMILAR REGIONAL YEARLY PERCENTAGE-RAINFALLS IN SOUTHERN TEXAS AND NEW MEXICO FOR EACH OF THE SAME 13 YEARS.

Year.	YEARLY AND CUMULATIVE RAINFALL PERCENTAGES, COMPARED WITH THE MEAN RAINFALL FOR THE 13 YEARS AS 100 PER CENT.				
	YEARLY PERCENTAGES.		CUMULATIVE AND PROGRESSIVE PERCENTAGES.		
	Texas and New Mexico.	Mexico.	Period, in years.	Texas and New Mexico.	Mexico.
1901.....	86% = 100%	80% = 93%	1	86 ÷ 1 = 86% = 100%	80 ÷ 1 = 80% = 93.0%
1902.....	88% = 100%	97% = 110%	2	174 ÷ 2 = 87.0% = 100%	177 ÷ 2 = 88.5% = 101.7%
1903......	106% = 100%	93% = 88%	3	280 ÷ 3 = 93.3% = 100%	270 ÷ 3 = 90.0% = 96.5%
1904......	110% = 100%	110% = 100%	4	390 ÷ 4 = 97.5% = 100%	380 ÷ 4 = 95.0% = 97.5%
1905......	156% = 100%	152% = 97%	5	546 ÷ 5 = 109.2% = 100%	532 ÷ 5 = 106.4% = 97.5%
1906......	119% = 100%	126% = 106%	6	665 ÷ 6 = 110.8% = 100%	658 ÷ 6 = 109.7% = 99.0%
1907......	109% = 100%	96% = 88%	7	774 ÷ 7 = 110.6% = 100%	754 ÷ 7 = 107.7% = 97.4%
1908......	86% = 100%	84% = 98%	8	860 ÷ 8 = 107.5% = 100%	838 ÷ 8 = 104.7% = 97.4%
1909......	70% = 100%	85% = 122%	9	930 ÷ 9 = 103.3% = 100%	923 ÷ 9 = 102.6% = 99.4%
1910......	57% = 100%	50% = 88%	10	987 ÷ 10 = 98.7% = 100%	973 ÷ 10 = 97.3% = 98.6%
1911......	109% = 100%	122% = 112%	11	1 096 ÷ 11 = 99.8% = 100%	1 095 ÷ 11 = 99.6% = 99.8%
1912......	94% = 100%	91% = 97%	12	1 190 ÷ 12 = 99.3% = 100%	1 186 ÷ 12 = 98.9% = 99.6%
1913......	115% = 100%	113% = 98%	13	1 305 ÷ 13 = 104.4% = 100%	1 299 ÷ 13 = 100.0% = 99.6%
Sum.....	(1 305 = 100)	(1 299 = 99.6)			
Mean.....	100 + = 100%	100 − = 99.6%	13	.... 100%	.... 99.6%

Messrs. Duryea and Haehl. Presidio, Tex., and Ojinaga, Mexico, and the estimated flows of the Rio Nazas for the 15 years, 1897-1911, presumably near its mouth and near Torreon, Mexico.

TABLE 82.—MEAN YEARLY RAINFALL OF THE 13 YEARS, 1901-13, AT EACH OF FOURTEEN STATIONS IN SOUTHERN TEXAS AND NEW MEXICO, COMPARED WITH THE MEAN YEARLY RAINFALL AT EACH STATION FOR THE LONGER PERIODS OF 47 TO 19 YEARS, ENDING WITH 1913.

Station.	Mean Yearly Rainfall, in Inches.			
	Of the 13 years. 1901-13.	Of the 47 to 19 years ending with 1913.		
San Marcial	9.13 in. = 100%	47 years.	9.25 in.	= 101.3%
Mesilla Park	9.02 in. = 100%	47 years.	8.60 in.	= 95.3%
Fort Union	17.24 in. = 100%	47 years.	18.15 in.	= 105.3%
Santa Fé	13.83 in. = 100%	47 years.	14.01 in.	= 101.3%
Fort Davis	14.56 in. = 100%	47 years.	16.86 in.	= 115.8%
El Paso	9.72 in. = 100%	47 years.	9.20 in.	= 94.8%
Fort Stanton	15.80 in. = 100%	47 years.	16.35 in.	= 103.5%
Deming	9.31 in. = 100%	45 years.	9.64 in.	= 103.5%
Fort Stockton	13.78 in. = 100%	45 years.	15.15 in.	= 110.0%
Fort Clark	20.23 in. = 100%	43 years.	21.24 in.	= 105.0%
San Antonio	24.94 in. = 100%	43 years.	27.94 in.	= 112.0%
Fort McIntosh	18.72 in. = 100%	43 years.	19.64 in.	= 104.8%
Eagle Pass	19.24 in. = 100%	42 years.	21.20 in.	= 110.2%
Roswell	12.91 in. = 100%	19 years.	14.16 in.	= 109.7%
Average	14.90 in. = 100%	47 to 19 years.	15.82 in.	(105.2) = 106.1%

The Rio Conchos flows are the differences in the flows of the Rio Grande above and below the mouth of the Rio Conchos, as measured by the International Boundary Commission, and are believed to be reasonably accurate measures of the flows of that river. No data are easily available, however, for the corresponding Rio Grande drainage areas; hence its flows per square mile from Mexico, Texas, and New Mexico cannot be included in the comparison.

The Rio Nazas data are from the records of a Mexican Government Commission, but are known to be based merely on measurements of cross-sections, slopes, and gauge heights, used in conjunction with assumed Kutter coefficients to estimate stream flows.

The drainage area of the Rio Conchos above its mouth is believed (from probably fairly reliable maps, supplemented by some surveys) to be very nearly 23 000 sq. miles; the Rio Nazas drainage area above the point of its stream gauging is believed to be not far from 13 000 sq. miles.

Because of the inaccuracies of the Rio Nazas flows and drainage area, no comparison can be made of its flows per square mile with those of the Rio Conchos, and all comparisons must be restricted to

the comparative characteristics of their stream flows, rather than to their comparative flows. Messrs. Duryea and Haehl.

Torreon, near the mouth of the Rio Nazas, is nearly 300 miles south of the mouth of the Rio Conchos.

Comparisons of the stream flow characteristics of these rivers are given in Tables 83 and 84.

TABLE 83.—YEARLY STREAM FLOWS OF THE RIO CONCHOS AND THE RIO NAZAS FOR EACH OF THE 12 YEARS, 1900-11, EXPRESSED AS PERCENTAGES OF THE MEAN YEARLY STREAM FLOW FOR THE 12 YEARS.

Year.	For Each Year.		Cumulative or Progressive Mean.		
	Conchos.	Nazas.	Number of years.	Conchos.	Nazas.
1900......	74% = 100%	83% = 112%	1	74% = 100%	83% = 112%
1901......	27% = 100%	34% = 126%	2	50% = 100%	57% = 114%
1902......	103% = 100%	76% = 74%	3	68% = 100%	65% = 96%
1903......	46% = 100%	79% = 172%	4	62% = 100%	68% = 110%
1904......	158% = 100%	84% = 53%	5	81% = 100%	71% = 88%
1905......	174% = 100%	242% = 139%	6	97% = 100%	100% = 103%
1906......	198% = 100%	233% = 118%	7	111% = 100%	119% = 107%
1907......	92% = 100%	53% = 58%	8	109% = 100%	110% = 101%
1908......	68% = 100%	70% = 103%	9	104% = 100%	106% = 102%
1909......	95% = 100%	136% = 143%	10	103% = 100%	109% = 106%
1910......	40% = 100%	32% = 80%	11	98% = 100%	102% = 104%
1911......	127% = 100%	80% = 63%	12	100% = 100%	100% = 100%
Average.....	100% = 100%	100% = 103.4%	12	....	....

As might be expected, even if the flow characteristics of the two rivers were nearly the same (because of the inaccurate method of the Rio Nazas measurements), the Nazas characteristics of the separate years vary rather widely from those of the Conchos, namely from — 47 to + 72%; but the average variation for the 12 years is only + 3.4%; after 3 years, the progressive maximum variations are only — 12 to + 10%; and, after 5 years, the maximum progressive variation is only + 7 per cent.

Not only are the characteristics of the yearly stream flows of the two rivers very similar, but the divisions of the yearly stream flows among the 12 months also are similar as shown by Table 84.

In Table 84 the separate monthly percentages of the year's stream flow vary from only 0.6 to 3.2% for the two rivers, with extremes of — 3.2% (July) to + 2.7% (August); and the cumulative or progressive means have a maximum difference for the two rivers of only 9.7% (for the 7 months, January to July).

It is evident, also, from Table 84, that both rivers have the same well-defined coincident flood season of 3 months (July to September, inclusive), during which the flood flows of the Rio Conchos average

Messrs. Duryea and Haehl. about 67.3% of its year's flow, and the floods of the Rio Nazas about 68.1% of its year's flow.

Mean Temperatures.—That the characteristics of mean monthly temperature are quite uniform throughout Texas and New Mexico, and similar to those at La Boquilla, is shown by a consideration of Fig. 14; and by Table 85, compiled from Plate XXXI, Table 37, and later information.

TABLE 84.—CLOSE CORRESPONDENCE BETWEEN THE MONTHLY PERCENTAGE STREAM FLOWS OF THE RIO NAZAS AND THE RIO CONCHOS. MEANS OF THE 12 YEARS, 1900-11.

Month.	For Each Month.			Cumulative or Progressive Mean.			
	Conchos.	Nazas.	Difference.	Number of months.	Conchos.	Nazas.	Difference.
January	2.4%	1.6%	— 0.8%	1	2.4%	1.6%	— 0.8%
February	3.0%	1.2%	— 1.8%	2	5.4%	2.8%	— 2.6%
March	1.5%	0.4%	— 1.1%	3	6.9%	3.2%	— 3.7%
April	0.7%	0.1%	— 0.6%	4	7.6%	3.3%	— 4.3%
May	1.0%	0.3%	— 0.7%	5	8.6%	3.6%	— 5.0%
June	2.6%	1.3%	— 1.3%	6	11.4%	4.9%	— 6.5%
July	15.3%	12.1%	— 3.2%	7	26.7%	17.0%	— 9.7%
August	21.3%	24.0%	+ 2.7%	8	48.0%	41.0%	— 7.0%
September	30.7%	32.0%	+ 1.3%	9	78.7%	73.0%	— 5.7%
October	9.5%	12.2%	+ 2.7%	10	88.2%	85.2%	— 3.0%
November	5.8%	8.1%	+ 2.3%	11	94.0%	93.3%	— 0.7%
December	6.0%	6.7%	+ 0.7%	12	100.0%	100.0%	— 0.0%
Year	100%	100%	....	..	......	......	....

The Botello power-house of Table 85 is within "a long day's horseback ride" of Morelia, capital of the State of Michoacán, Mexico; and has almost the same altitude, climate, and conditions as Morelia.

From a small-scale map, Morelia is almost directly west of the City of Mexico and about 130 miles distant; it is about 540 miles farther south and 260 miles farther east than La Boquilla (at the east end of Lake Conchos), and 600 miles from it in an air line.

Mean temperatures at the Botello power-house were furnished through the courtesy of T. K. Mathewson, M. Am. Soc. C. E., and Messrs. Curtis and Hine, Colorado Springs, Colo., General Managers of the Guanajuato Power and Electric Company. This information will be used hereinafter to check the applicability of Fig. 4 to the quick estimation of an approximate value for the yearly evaporation depth from a reservoir at the Botello power-house, as compared with the *1.72 m., 5.64 ft., or 67.6 in. adopted by Messrs. Curtis and Hine.

* The 1.45 m. given by Mr. Mathewson on p. 2687 of *Proceedings*, Am. Soc. C. E., for December, 1915, was in error, and subsequently was corrected by him to 1.718 m.

Messrs. Duryea and Haehl.

TABLE 85.—Comparative Mean Monthly Temperatures Throughout Texas and New Mexico, and at La Boquilla, Mexico.

Station.	Elevation above sea level, in feet.	Mean Yearly Temperature, in Degrees Fahrenheit. Temperature.	Departure from average.		Mean Monthly Temperature, in Degrees, Fahrenheit. July.	January.	Difference.	Departure from average.	
Abilene, Tex	1 740	62.1	......	0.7	83.9 (1887)	38.9 (1888)	= 45.0	+ 9.7	....
Austin, Tex	600	69.2	+ 6.4	......	84.2 (1911)	56.5 (1911)	27.7	....	— 7.6
Brownsville, Tex	50	71.0	+ 8.2	......	81.2 (1887)	55.0 (1888)	26.2	....	— 9.1
Corpus Christi, Tex	20	69.4	+ 6.6	......	82.9 (1887)	48.3 (1888)	34.6	....	— 0.7
El Paso, Tex	3 762	63.6	+ 0.8	......	80.9 (1887)	44.8 (1888)	36.1	+ 0.8	....
" " "	3 762	....	......	......	81.0 (1912)	.... (1912)	....	....	....
" " "	3 762	61.5	......	— 1.3	81.5 (1913)	40.0 (1913)	41.5	+ 6.2	....
Fort Bliss, Tex	3 700	65.3	+ 2.5	......	83.0 (1889)	48.3 (1890)	34.7	....	— 0.6
" " "	3 700	64.8	+ 2.0	......	82.3 (1890)	48.3 (1890)	34.0	....	— 1.3
Fort Davis, Tex	4 930	59.7	......	— 3.1	75.4 (1887)	45.0 (1888)	30.4	....	— 4.9
Galveston, Tex	6	68.7	+ 5.9	......	81.9 (1887)	49.8 (1888)	32.1	....	— 3.2
Palestine, Tex	500	64.1	+ 1.3	......	82.0 (1887)	43.4 (1888)	38.6	+ 3.3	....
Rio Grande City, Tex	230	71.4	+ 8.6	......	84.5 (1887)	54.7 (1888)	29.8	....	— 5.5
San Antonio, Tex	700	66.8	+ 4.0	......	83.8 (1887)	48.0 (1888)	35.8	+ 0.5	....
Albuquerque, N. Mex	5 000	56.5	......	— 6.3	79.1 (1900)	35.4 (1901)	43.7	+ 8.4	....
" " "	5 000	54.1	......	— 8.7	75.2 (1903)	36.3 (1903)	38.9	+ 3.6	....
Carlsbad, N. Mex	3 000	63.1	+ 0.3	......	80.6 (1899)	42.2 (1899)	38.4	+ 3.1	....
" " "	3 000	64.1	+ 1.3	......	80.2 (1901)	44.7 (1901)	35.5	+ 0.2	....
Elephant Butte, N. Mex	4 250	61.1	......	— 1.7	81.1 (1909)	42.5 (1910)	38.6	+ 3.3	....
Fort Stanton, N. Mex	6 150	50.0	......	— 12.8	65.6 (1887)	36.3 (1888)	29.3	....	— 6.0
Lake Avalon, N. Mex	3 200	63.8	+ 1.0	......	82.0 (1909)	46.4 (1910)	35.6	+ 0.3	....
Santa Fé, N. Mex	7 013	48.9	......	— 13.9	66.9 (1887)	30.3 (1888)	36.6	+ 1.3	....
Average (of 20-21)	.....	62.8	(+ 48.9) + 3.8	(— 48.5) — 6.1	80.0	44.7	(35.3) 35.3	(+ 40.7) + 3.4	(— 38.9) — 4.3
‡La Boquilla, Mex	4 300	67.5	+ 0.6	......	85.0 (1912)	†(51.0) (1912)	(34.0)	+ 5.8	....
" " "	4 300	65.2	......	— 1.7	81.0 (1913)	52.0 (1913)	= 29.0	+ 0.8	....
" " "	4 300	68.4	+ 1.5	......	80.9 (1914)	64.3 (1914)	16.6	....	— 11.6
" " "	4 300	66.5	......	— 0.4	82.2 (1915)	49.1 (1915)	33.1	+ 5.9	....
Average (of 4-3)	4 300	66.9	(+ 2.1)	(— 2.1)	82.3	51.1	(28.0) 28.2	(+ 12.5)	(— 11.6)
Botello power-house,* State of Michoacán, Mexico	6 560 (2 000 m.)	62.5 (1915)	....	....	67.8 (1915) 67.8 (1915)	55.2 (1915) 57.4 (1916)	= 12.6 = 10.4	....	....
						Average.....	11.5	....	....

* See description following. † Average of Maximum and Minimum (Table 86). ‡ At east end of Lake Conchos.

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In Table 85 the average mean temperatures for July and January at the seventeen stations in Texas and New Mexico are 80.0° Fahr. (July) and 44.5° Fahr. (January); and those at La Boquilla are 82.3 and 50.1°; the average difference between the July and January temperatures is 35.4° at the Texas and New Mexico stations, and 31.3° at La Boquilla; and the departures from the means vary but little.

Table 85 also shows that the variations at La Boquilla between the yearly mean temperatures, the means for January, and those for July were comparatively small during the 4-year period, 1912-15, one year being on the whole much like another; and, that at the Botello power-house, though the mean yearly temperature is only about 4° Fahr. lower than that at La Boquilla, the January mean temperature apparently is about 14° lower; and the excess of the July over the January mean temperature apparently is about 17° less than at La Boquilla.

It should be noted that some of the stations in Table 85 are outside the limits of the "Great Plateau".

Table 85 contains only yearly mean temperatures and those for July and January. Throughout the Plateau portion of Texas, New Mexico, and Arizona the nights usually are much colder than the days; and that the same condition holds at La Boquilla also is shown by Table 86, which gives the averages of the daily readings throughout each month by a maximum and minimum thermometer. Table 86 also defines more closely the temperature conditions at La Boquilla.

From the foregoing data of rainfalls, stream flows, and mean temperatures it is apparent that, at least in those respects, the climatological conditions are quite uniform throughout Southern Texas and New Mexico and Northwestern Mexico; and this uniformity was even more apparent from diagrams than from tables.

It is regretted that data relating to humidity, sunshine, wind, etc., were not secured at Lake Conchos, as suggested by Mr. Meyer, but this was prevented by the extreme difficulties of instituting any kind of new work (even observations) in Mexico at that time, and by the need of quick results in a practical engineering problem.

Referring to some criticisms, the investigation was not intended to be, nor was it considered, a "scientific" one, but was frankly empirical, making use of such observed evaporation depths in Southern Texas and New Mexico as were of record to estimate (by empirical modifications) the probable yearly evaporation depth in Northern Mexico. However, the writers do not admit in any spirit of apology that their work was empirical. On the contrary, they believe that "scientific" methods of investigating evaporation (such as that of Professor Bigelow, which was an investigation of the law of evaporation rather than of its amount) are of comparatively little value in practical engineering problems, and this view seems to be Mr. Grunsky's also.

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TABLE 86.—AVERAGE MAXIMUM AND MINIMUM TEMPERATURES AT LA BOQUILLA, MEX., FOR EACH MONTH; BEING THE AVERAGES OF THE DAILY MAXIMUM TEMPERATURES ON A MAXIMUM THERMOMETER, AND OF THE DAILY MINIMUM TEMPERATURES ON A MINIMUM THERMOMETER.

Month.	YEAR 1912.			YEAR 1913.			YEAR 1914.			YEAR 1915.			AVERAGE FOR 4 YEARS. AVERAGE OF COLUMNS.			
	Maximum.	Minimum.	Difference.	Maximum.	Minimum.	Difference.	Maximum.	Minimum.	Difference.	Maximum.	Minimum.	Difference.	(1), (4), (7), and (10). Maximum.	(2), (5), (8), and (11). Minimum.	(3), (6), (9), and (12). Difference.	(13) and (14). Mean.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
January	*(66°)	†(36°)	‡(30°)	67°	37°	30°	69°	(36°)	(33°)	63°	§35°	28°	66.2°	36.0°	30.2°	51.1°
February	(70)	(41)	(29)	68	45	23	73	40	33	70	39	31	70.3	41.3	29.0	55.8
March	(74)	(45)	(29)	76	51	25	74	43	31	71	41	30	73.7	45.0	28.7	59.3
April	85	(56)	(29)	82	61	21	89	55	34	85	52	33	85.2	56.0	29.2	70.6
May	95	(62)	(33)	93	66	27	96	62	34	96	58	38	95.0	62.0	33.0	78.5
June	97	(65)	(33)	93	65	28	96	66	30	‖104.5	65	40	97.6	65.2	32.7	81.4
July	98	(66)	(30)	93	70	23	96	66	30	¶101.3	63	38	97.1	66.3	30.3	81.7
August	92	67	25	89	65	24	94	66	28	92	56	36	91.7	63.5	28.2	77.6
September	88	62	26	79	57	22	87	61	26	90	55	35	86.0	58.7	27.3	72.3
October	81	54	27	73	(51)	(33)	80	54	26	90	44	46	81.0	50.7	33.0	65.8
November	69	41	28	65	(41)	(34	70	47	23	85	35	50	72.2	41.0	33.7	56.6
December	64	39	25	58	(34)	(34)	64	36	28	77	**28	49	65.7	34.5	34.0	50.1
(Average)	......	......	(28.7)	......	......	(27.0)	......	......	(29.7)	......	......	(37.8)	......	......	......	......
Year	81.6°	52.8°	28.8°	78.0°	53.6°	24.4°	82.3°	52.7°	29.6°	85.4°	47.6°	37.8°	81.8°	51.7°	30.8°	66.8°

All values in parentheses are for times during which the corresponding thermometers were broken or out of order.

* Mean of Columns (4), (7), and (10).
† Mean of Columns (5), (8), and (11).
‡ Mean of Columns (6), (9), and (12), etc.

Minimum and Maximum Daily Temperatures, in Degrees, Fahrenheit:
§ Minimum—January, 1915; 18th = +21°, 19th-21st = +23° (heavy snowstorm).
‖ Maximum—June, 1915; 18th and 27th = 108°.
¶ July, 1915; 1st = 111°.
** Minimum—December, 1915; 22d and 25th = + 19°, 29th = + 18°.

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As to empirical methods, large and important parts of the field of engineering are dependent almost wholly on empiricism. One of the most familiar examples is the flow of water, the useful knowledge of which has been almost wholly empirical, ever since the first appearance of the empirical Chezy formula in 1775.

The practical engineering problems before the writers in the investigation of the Rio Conchos or La Boquilla project were as follows:

A.—The estimation of the safe water supply and power production of the project;

B.—Reports on the safety of the foundations of each of the three dams; on the safety of the plans and of the past construction; and on plans and cost for the completion of the project;

C.—A preliminary report on the irrigation opportunities.

Also, the time for the investigation was somewhat limited by the fact that it was desired to resume as soon as practicable the then abandoned construction work, and push it to completion as rapidly as possible, and because the results of the new investigations were necessary as precedents to the re-financing of the project, the former financial arrangements having been disturbed by the effects of the war in Mexico which caused the temporary abandonment of the construction in September, 1913.

The determination of a reasonably safe value for the yearly evaporation depth, even though more important than usual, was, after all, only a minor factor in *A*. The evaporation depth had to be made use of early in the investigation of *A*, however, for the following reason:

The stream flow data of the Rio Conchos consisted of 14 years (1900-13) measured flows at its mouth (its junction with the Rio Grande), and of 4 years (1910-13) measured flows at La Boquilla. However, the flows of 1912 and 1913 at La Boquilla were measured largely by their being impounded in the surveyed reservoir of Lake Conchos, and hence were exclusive (as impounded) of the large evaporation losses from the lake. The flows of 1910-13 were necessary as data to establish a safe proportion between the flow of the Rio Conchos at La Boquilla and that at its mouth; hence the evaporation depth, as estimated and checked up to the middle of February, 1914, had to be made use of at once, in order not to delay the more important and more protracted investigation of the safe water supply and power production. As a precaution, the observations of pan evaporation at Lake Conchos were continued until June, 1914, when preliminary statements of conclusions were rendered to the Company; and the final reports were completed in October and November, 1914.

The pan measurements of evaporation were continued at Lake Conchos for several months after June, 1914, but this was not learned by the writers until December, 1915. Efforts were made to secure the

notes of the later pan measurements for use in this closure, but the La Boquilla project (which had been operating commercially since September 29th, 1915, selling some of its electric power to mines at Parral) was again abandoned in January, 1916, before the notes were secured. The furnishing of power to Parral was resumed on July 25th, 1916, but the notes of the additional pan evaporations have not yet been secured. Messrs. Duryea and Hachl

The various discussions on the paper will now be considered. In answering them the writers will group together all comments on the same subject, as far as practicable.

Salton Sea Evaporation Pans Circular, and not Square.—As stated by Messrs. C. E. Grunsky,* Charles W. Comstock,† and Charles H. Lee,‡ the evaporation pans used by Professor Bigelow in his Salton Sea experiments were circular, instead of square, as erroneously assumed by the writers. In making their investigation of the evaporation from Lake Conchos, and even later in preparing the paper, the writers had access only to a summary of the Salton Sea experiments, giving the conclusions reached, but describing only inadequately the methods and apparatus. From that information it was assumed that the Bigelow experiments were carried out in accordance with usual practical engineering methods, and with usual standard apparatus—and hence that the pans were square.

However, while acknowledging their error in assuming the Salton Sea evaporation pans to have been square, when in fact they were circular, it is hard to believe that any material error can arise therefrom, and this view apparently is Mr. Comstock's also. Although the evaporation depth from a pan 3 ft. square may be slightly different from that from a pan 3 ft. in diameter, it seems very unlikely that (from a practical engineering standpoint) any material error can result from applying the relative observed evaporation depths from a series of pans 2, 3, 4, etc., ft. in diameter, to a series of pans 2, 3, 4, etc., ft. square.

Subsidiary Conclusion (a) of Table 2.—This conclusion (of Professor Bigelow, but accepted and used by the writers) gives the presumed relative evaporation depths from a series of 2-ft. to 6-ft. pans, all the conditions of climate, exposure, etc., supposedly having been identical, and the evaporation conditions varying only in the sizes of the pans.

As stated already, in discussing square *versus* circular pans, it was assumed by the writers (incorrectly) that the Salton Sea evaporation experiments of Professor Bigelow were made on practical engineering lines; and indeed that seems to have been the earnest desire of Mr.

* *Proceedings,* Am. Soc. C. E., for April, 1916, pp. 561–63.

† *Proceedings,* Am. Soc. C. E., for March, 1916, pp. 384–85.

‡ *Proceedings,* Am. Soc. C. E., for December, 1915, p. 2708.

Messrs. Duryea and Haehl. Grunsky, a member of the Conference Board which outlined a programme for the work.

It is apparent, however, from information given in Mr. Grunsky's discussion,* that the "floating-pans" were not floating in the usual sense; but that, instead (with a depth of pan of 10 in. and of contained water of presumably about 8 to 9 in.), they were immersed in the water of a slough only about 3 or 4 in.

However, in investigating the effect of size of pan on evaporation depth, Professor Bigelow used three series of pans:

(1) Two pans of different sizes alongside each other, one perhaps on a platform and the other on the ground, but presumably not banked by earth, as is usual with "land-pans";

(2) Three pans of different sizes on a tower platform, half a mile from shore, and as close to the water surface as was practicable; and

(3) Four pans of different sizes, supported by adjoining rafts so that the pans were immersed only 3 or 4 in. in the water of a slough;

and, of these three series of tests, Professor Bigelow states "the ratios [of evaporation depth, from pans of different sizes] are quite steady and the results have been incorporated into the final values of the coefficient, C_2".

The full range of practical conditions for an engineering investigation of pan evaporation, of course, should have had as extremes "land-pans" embedded in or banked around with earth, and "floating-pans" floating free and thus fully immersed in water; and it is much to be regretted that Professor Bigelow's tests did not include such extreme conditions. However, his Series (1) approximated the land-pan condition, his Series (3) the floating-pan condition, and his Series (2) was in a condition intermediate between (1) and (3). Thus, out of five conditions, he investigated three, throughout which range the ratios were "quite steady"—presumably meaning by this nearly constant. Hence, if the results of the three series which were investigated are plotted on a diagram, with the "conditions" as abscissas and the values of C_2 as ordinates, it would not be an unusual assumption, or one which is not often resorted to in engineering investigations, if the approximately horizontal line representing the value of C_2, throughout the range of the three conditions which were investigated, should be extended or projected—on the one hand to include the full "land-pan" conditions, and on the other to include the full conditions of "floating-pans".

It is much to be regretted that the two conditions of banked land-pans and full floating-pans were not included by Professor

* *Proceedings*, Am. Soc. C. E., for April, 1916, p. 561.

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Bigelow in his investigations, especially as only those two conditions are of direct value in practical engineering investigations of evaporation. Nevertheless, it seems to the writers that the conclusions embodied in (*a*) of Table 2 still presumably are true to within a fair degree of approximation, even when applied to "land-pans" and to "floating-pans"; and that (until and unless proven so to be untrue by further and direct investigation) the values of (*a*) may be used to modify evaporation depths measured in land- or floating-pans of different sizes to the presumptive depths, if pans of a uniform size had been used, without fear of thus introducing material errors into the operation and into its final results.

At the very least, it is believed that comparisons between evaporation depths from pans of different sizes thus modified for sizes of pans, will show relations much nearer the true ones than if the depths are not so modified. The writers are not aware of any other or better established relations between evaporation depths from pans of different sizes than those advanced by Professor Bigelow, and none has been pointed out by any of those who have discussed the paper. It is admitted that these values should not be accepted as final or conclusive for the usual conditions of land-pans and floating-pans, and it is not thought that they were thus considered, even by Professor Bigelow. However, until further tests and the establishment of more reliable values, it is believed that the value and truth of combinations of evaporation depths observed in pans of different sizes will be increased materially by the use of Professor Bigelow's values to modify (before combination) the observed depths to a uniform size of pan.

Mr. Grunsky's statement,* that the values of Subsidiary Conclusion (*a*), Table 2, apply only to a factor in the formula for the evaporation depth, and not to the evaporation depth itself, is of course true. However, the other factors in the formula apparently are almost independent of the size of the pan, and the variable, C_2, is apparently of preponderating influence on the evaporation depth; hence it does not seem that the assumption that the relative evaporation depths vary as do the values of C_2 should lead to material error.

Mr. Grunsky's formula,

$$C_2 = 0.023 + 0.010 \frac{p}{a},$$

for land-pans 10 in. deep, not embedded in the soil, in a climate comparable with that of the Salton Sea, is of much interest as expressing the variable value of C_2 in terms only of the size of pan, and with values in practical agreement with those of Professor Bigelow.

* *Proceedings*, Am. Soc. C. E., for April, 1916, p. 561.

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Mr. Comstock gives values of C_2* as Professor Bigelow's which differ materially from those given in that writer's "Abstract of Data No. 4", and repeated in Table 7. When compared for relative values, however (the only values of interest in connection with Subsidiary Conclusion (*a*)), it is found that for 4-ft. and 6-ft. pans the relative values of C_2 are almost identical for the two sets—though this close correspondence does not hold for the 2-ft. pan.

Mr. Comstock's statement, that the higher water temperatures and greater evaporation depths, observed at Indio in 1907 to exist in smaller than in larger pans, are to be expected in land-pans but cannot exist in floating-pans, does not appear to the writers to be justified. It is presumable that the higher temperatures are due to a continuous (during sunshine) accession of heat to the small confined body of water from sun heat on the metal rim and bottom of the pan, such heating effect evidently being greater in smaller than in larger pans; and it is to be expected that floating- as well as land-pans will be thus affected, though perhaps to a less degree.

As stated by Mr. Comstock, Professor Bigelow's explanation of the reason that evaporation depths are greater from smaller than from larger pans (because of the more effective clearing of the vapor blanket from the smaller pans by wind action) does not seem convincing as accounting for the sole or even the most important cause. It is believed that a much more important cause is that suggested by Mr. Grunsky: the evaporation (by sun heat on the metal rim of the pan and by wind action) of the thin film of water drawn up on the inside of the pan by the capillary action of the pan surface. It is evident that the evaporation depth from this cause must increase as the size of pan decreases.

Also, it is not unlikely that other causes, as yet unrecognized, contribute to make the evaporation depths from small pans greater than those from larger ones.

Subsidiary Conclusion (*b*) *of Table 2.*—This conclusion is the writers', not one of Professor Bigelow's, and is that the evaporation depth from a "floating-pan" is about 80% of that from a near-by "land-pan" of the same size.

Conclusion (*b*) is discussed by Messrs. Grunsky,* Lee,† Comstock,‡ Post,§ Ledoux,‖ and Hawgood¶; and the various values advanced for it are given in Table 87.

The Kingsburg evaporation depths of Mr. Grunsky were measured in pans 3 ft. square and 15 in. deep, with the water in the pans 10 in.

* *Proceedings*, Am. Soc. C. E., for March, 1916, p. 386.

Proceedings, Am. Soc. C. E. for:
* April, 1916, pp. 567–69.
† December, 1915, p. 2708.
‡ March, 1916, pp. 386–87.
§ December, 1915, pp. 2691–92, 2702.
‖ May, 1916, pp. 794–96.
¶ February, 1916, pp. 247–49.

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TABLE 87.—VARIOUS VALUES ADVANCED FOR THE PROPORTION WHICH THE EVAPORATION DEPTH FROM A FLOATING-PAN BEARS TO THAT FROM A NEAR-BY SIMILAR LAND-PAN OF THE SAME SIZE.

(For the full cycle of a year.)

Authority.	Locality.	Period and dates.	No. of Pans. Floating.	No. of Pans. Land.	Evaporation depth from floating-pans. as a percentage of that from land-pans.
C. E. Grunsky.......	Kingsburg, Cal..............................	4 years, 1881-85..........................	1	1	78%
C. H. Lee...........	Owens River, Cal..........................	1 year, 1910-11..........................	1	1	75%
C. W. Comstock.....	Coyote, Cal., and Granite Reef, Ariz........	2 years, Coyote, and 1 year Granite Reef...	3	4	82%
Mean................	Arid regions.................................	6½ years	5	6	78%
W. S. Post..........	San Diego, Cal..............................	33 months, January, 1913-September, 1915.	6	4	99%
W. S. Post..........	San Diego, Cal..............................	5 months, May-September, 1915	1	1	98%
J. W. Ledoux........	Allegheny Mountains, Pa....................	Several months, 1888-89..................	..	..	*100%
H. Hawgood.........	....	....	..	..	No fixed relation
Duryea and Haehl ..	Coyote, Cal..................................	1 year, 1904..............................	2	3	72.8%
Duryea and Haehl ..	Coyote, Cal..................................	1 year, 1905..............................	2	3	85.0%
Mean................	Coyote, Cal..................................	2 years, 1904-05.........................	2	3	78.9%

* "Land gages give the same results as floating gages, provided the temperature of the water in the evaporating vessel is kept the same as that of the water in the reservoir".

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or less in depth. The floating-pan was floating in the Kings River. The land-pan was on a railroad trestle for the first 3 months, exposed on all sides to sun and air, and after that on land, set a few inches in the ground, and with earth embanked around it to the elevation of its water surface.

The Owens River evaporation depths of Mr. Lee were measured in pans 3 ft. square and 10 in. deep, with the water in the pans 8 in. or less in depth. The land-pan was embedded in the ground, and the floating-pan floated with from 1 to 5 ft. depth of water beneath it, depending on the stage of the river.

Mr. Comstock's value, 82%, is one derived from Tables 8 and 11, by rejecting the values for Salton Sea and California, Ohio, and combining those for Coyote (24 months), Granite Reef (presumably 12 months), and Lake Conchos (5 months, Table 11), with a resultant weighted mean of 81.5 per cent. If it is worth while to weight the different values, it would seem more logical to give the Coyote value double the weight corresponding to its 24 months (because of its two floating-pans and three land-pans) and to include also the 2-months Lake Conchos value of Table 10. The weighted value would not have been changed materially thereby, however, it being then 81.8 per cent.

The San Diego evaporation depths of Mr. Post were obtained in pans 3 ft. square and 18 in. deep, with the water in the pans presumably about 16 in. or less in depth. The pans giving his second value (for 5 months only) are included with those giving his value for the 33 months.

The Coyote evaporation depths of the writers were measured in pans 3 ft. square and 12 in. deep, with the water in the pans about 10 in. or somewhat less in depth. The land-pans were embedded in the ground and banked around by earth nearly to their rims; and the floating-pans floated on the Laguna Seca with from 3 to 6 ft. of water beneath them, depending on the stage of the lagoon.

For the full cycle of a year, all the authorities of Table 87, except Messrs. Post, Ledoux, and Hawgood, are in practical agreement with the value of "about 80%" adopted by writers. As values in the field of hydrography, rainfall, etc., Mr. Comstock's results, 83.4% (unweighted) and 82% (weighted), are regarded by the writers as satisfactory agreements with the adopted 80% value, rather than as material disagreements.

The values of Messrs. Post, Ledoux, and Hawgood (and of Table 87 in general), will be discussed hereinafter, in connection with the consideration of Table 88—data of the relative observed evaporation depths from land-pans and from floating-pans, for periods shorter than the full cycle of a year. The evaporation tests of Table 88 are those by Messrs. Grunsky and Lee, and by the writers in Table 87 in monthly detail.

From Table 87 it is apparent that Mr. Post's conclusion from his San Diego experiments (that yearly evaporation depths from floating-pans are about the same as those from land-pans, both for a full cycle of a year and for the summer season only), Mr. Ledoux' conclusion to the same effect, and Mr. Hawgood's conclusion (that the relation between the evaporation depths from land- and floating-pans is a variable one, depending on many other influences than the floating and land conditions, and not expressible by a practically constant percentage)—all three are in disagreement with all the other data in Table 87 for this relation. Messrs. Duryea and Haehl.

Because of the fairly full data of Table 87 to the contrary (derived from experiments at three widely separated places and extending over periods of from 1 to 4 years), it is believed that Mr. Post's San Diego conclusion is not true generally elsewhere, but was due to the influences of some unknown and unrealized local differences of climate and exposure, as between his land-pans and his floating-pans; and that this explanation applies also to Mr. Ledoux' conclusion.

And, notwithstanding Mr. Hawgood's conclusion, it is still believed that (with the land-pans embedded in the ground or embanked around with earth, and with the floating- and land-pans identical in size, material, etc., and with identical conditions of exposure, etc.) there is in general (at least for full yearly cycles) a fairly constant relation between evaporation depths from land-pans and those from floating-pans, and that the evaporation depths from floating-pans are about 80% (at least for full yearly cycles) of those from land-pans of the same size, as adopted for Subsidiary Conclusion (*b*) by the writers.

Except Columns (3), (13), and (20) to (23), all the columns of Table 88 were derived by dividing the inches of depth of evaporation in the floating-pan by the inches of depth in the land-pan, for the corresponding single months or for the longer continuous periods of from 2 to 12 months; but Columns (3), (13), and (20) to (23) are merely means of the percentages given in certain of the other columns. Hence (except for the cumulative or progressive columns), the average of the twelve percentage values in each column will not check exactly the "year" percentage value at the bottom of the table. However, for Column (20) the average is only $(81.4 \div 77.3) = 105.2\%$ of the "year", and for Column (22) only $(82.5 \div 76.8) = 107.5\%$, and for three other columns, tried as rough checks, the differences are still less.

In Table 88 all the cumulative or progressive periods begin with January, and it is evident that different sets of progressive values would be obtained by beginning with February, March, etc., there being thus twelve sets of values, in all of which only those for 12 months would be identical.

However, the working out of such twelve sets of values would be too onerous and voluminous for any present use, and it is believed that

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TABLE 88.—DATA OF EVAPORATION DEPTHS FROM FLOATING-PANS, SIZE (ALL PANS 3 FT. SQUARE), FOR EACH MONTH OF THE

	Separate Months									Cumu			
	Coyote, Cal.			Kingsburg, Cal.					Owens River, Cal.		Coyote, Cal.		
Months.	Year 1904.	Year 1905.	2 Years Mean.	Year 1882.	Year 1883.	Year 1884.	Year 1885.	4 Years Mean.	1 Year Mean.	Total period, in months.	Year 1904.	Year 1905.	2 Years Mean.
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
	%	%	%	%	%	%	%	%	%		%	%	%
Jan.......	67.8	68.3	68.0	45.0	150.0	140.0	100.0	80.8	*76.7	1	67.8	68.3	68.0
Feb.......	48.1	104.0	76.0	109.5	142.8	83.3	107.7	109.0	*111.2	2	58.6	85.9	72.1
Mar......	69.6	99.3	84.4	67.9	98.4	81.0	109.0	90.5	70.4	3	63.6	91.9	77.7
Apr......	96.3	115.6	106.0	59.8	103.8	88.9	59.2	74.8	74.4	4	75.9	100.6	88.2
May......	61.2	71.3	66.2	36.5	51.6	80.0	51.6	51.1	78.1	5	68.9	90.0	79.4
June......	72.9	64 5	68.7	50.5	58.8	58.4	81.5	62.1	83.0	6	70.3	80 9	75.6
July......	73.2	72.2	72.7	61.4	78.3	56.8	79.0	69.5	67.7	7	71.1	78.1	74.6
Aug......	70.2	95.0	82.6	76.1	94.0	55.2	100.0	83.9	69.3	8	70.9	81.7	76.3
Sept.......	84.3	100.4	92.3	82.7	103.6	61.6	97.0	87.8	71.7	9	72.6	84.5	78.6
Oct.......	65.2	82.7	74.0	59.2	138.0	112.8	130.6	117.3	75.0	10	72.1	84.3	78.2
Nov......	91.7	95.0	93.4	115.0	121.5	166.7	†101.5	101.7	83.1	11	72.7	84.9	78.8
Dec.......	76.1	94.0	85.0	94.5	123 3	128.5	†95.2	94.1	77.0	12	72.8	85.0	78.9
(Average) Year......	72.8	85.0	78.9	‡67.4	‡89.5	‡77.2	‡91.5	77.7	75.2	Year.	72.8	85.0	78.9

* January and February of 1911, March to December of 1910.

† Values for November and December, 1885, equal mean values for those months

‡ Values actually observed during the 4 years were as follows:

November, 1881 to October, 1882 = 61.0%
" 1882 " " 1883 = 88.8
" 1883 " " 1884 = 72.7
" 1884 " " 1885 = 89.9 mean of the 4 years = 78.1 per cent.

§ Columns (3), (8), and (9) and (13), (18), and (19) are "weighted" for
Columns (3) and (13)—2 pairs of pans for 2 years = 4 pan (pair)—years.
Columns (8) and (18)—1 pair of pans for 4 years = 4 pan (pair)—years.
Columns (9) and (19)—1 pair of pans for 1 year = 1 pan (pair)—years.
"Weight" of Columns (22) and (23) = 9 pan (pair)—years.

sets of values for progressive periods beginning with other months than January can be worked out quickly and with sufficient accuracy by combinations of the percentages of Column (22) for the separate months.

The only progressive periods of special interest in connection with the Lake Conchos investigation are the following:

12 months (beginning at any month).

The 12 separate months.

AS PERCENTAGES OF THOSE FROM NEAR-BY LAND-PANS OF THE SAME YEAR, AND CUMULATIVELY FOR 1, 2, 3 TO 12 MONTHS. Messrs. Duryea and Haehl.

LATIVE OR PROGRESSIVE PERIODS.						MEANS OF SEPARATE MONTHS AND PROGRESSIVE PERIODS.			
Kingsburg, Cal.					Owens River.	Unweighted means of Columns:		§ Weighted means of Columns:	
						(3), (8), and (9).	(13), (18), and (19).	(3), (8), and (9).	(13) (18), and (19).
Year 1882.	Year 1883.	Year 1884.	Year 1885.	4 Years Mean.	* 1 Year Mean.	(Separate months).	(Progressive periods).	(Separate months).	(Progressive periods).
(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)
%	%	%	%	%	%	%	%	%	%
45.0	150.0	140.0	100.0	80.8	*76.7	75.2	75.2	74.7	74.7
67.2	145.5	136.0	107.1	96.7	*94 8	98.7	87.9	94 6	85.6
67.6	110.7	102.2	108.3	93.2	80.0	81.8	83.6	85.6	84 8
64.2	108.1	96.5	87.3	85.9	77.4	85.1	83.8	88.6	86.0
51.6	90.5	88.4	68.9	70.4	77.7	65.1	75.8	60.8	75.2
51.3	75.9	77.0	73.8	67.2	79.1	71.3	74.0	67 4	72.3
54.1	76.7	70.2	75.4	67.9	76.6	70.0	73.0	70.7	71.8
58.2	81.4	65.7	81.2	71.5	75.3	78.6	74.4	81.7	74.1
60.8	84.9	65.6	83.5	73.8	75 0	83.9	75.8	88.0	76 1
61.1	88.2	69.8	87.0	76.4	75.0	88.7	76.5	93.4	77.0
66.9	89.0	75.7	†91.3	77.4	75.3	92.7	77.2	95 9	77.8
67.4	89.5	77.2	†91.5	77.7	75.2	85.4	77.3	88.2	76.8
....	....	....	....	....	....	(81.4)	....	(82.5)	....
67.4	89.5	77.2	91.5	77.7	75.2	77.3	77.3	76.8	76.8

for the 4 years, November, 1881 to October, 1885, inclusive.

Columns (22) and (23) as follows:

Used by Mr. Post:

3 months, December to February;

4 " March to June;

5 " July to November.

Used by the writers for Lake Conchos:

2 months, (about) middle of January to early in March;

5 " (about) " " " " " " June;

4 " October to January (lake observations);

7 " October to April (" ").

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TABLE 89.—COMPARISON OF VARIOUS VALUES OF THE PROPORTION WHICH THE EVAPORATION DEPTH FROM A FLOATING-PAN BEARS TO THAT FROM A LAND-PAN, FOR VARIOUS PROGRESSIVE PERIODS LESS THAN 12 MONTHS.

Progressive periods and separate months.	Percentage, Inches in Floating-Pan ÷ Inches in Land-Pan.					
	Computed from Column (22) of Table 88.		Values advanced by Mr. Post.		Uniform value adopted by writers.	
	(1)	(2)	(3)	(4)	(5)	(6)
12 months (any consecutive 12)	76.8%	= 100%	99%	= 128.8%	80%	= 104.2%
Separate Months:						
January	74.7%	= 100%	150 ±%	= 193%	80%	= 115.2%
February	94.6%	= 100%	150 ±%	= 152%	80%	= 91.0%
March	85.6%	= 100%	108 ±%	= 121%	80%	= 100.4%
April	88.6%	= 100%	108 ±%	= 117%	80%	= 97.1%
May	60.8%	= 100%	108 ±%	= 171%	80%	= 141.4%
June	67.4%	= 100%	108 ±%	= 154%	80%	= 127.5%
July	70.7%	= 100%	90 ±%	= 122%	80%	= 121.6%
August	81.7%	= 100%	90 ±%	= 106%	80%	= 105.2%
September	88.0%	= 100%	90 ±%	= 98%	80%	= 97.8%
October	93.4%	= 100%	90 ±%	= 93%	80%	= 92.1%
November	95.9%	= 100%	90 ±%	= 90%	80%	= 89.8%
December	88.2%	= 190%	150 ±%	= 164%	80%	= 97.5%
(Average)	(82.5 = 107.5%)	(100%)	(111 = 112%)	(131.8%)	(80%)	(106.4%)
Year	76.8 = 100%	100%	99 = 100%	= 128.8%	80%	= 104.2%
December to February, inclusive (3 months—Post at San Diego)	79.8%	= 100%	134.0%	= 168.0%	80%	= 100.3%
March to June, inclusive (4 months—Post at San Diego)	70.4%	= 100%	96.5%	= 137.0%	80%	= 113.7%
July to November, inclusive (5 months—Post at San Diego)	80.0%	= 100%	80.4%	= 104.5%	80%	= 100.0%
January to March (*2 months—writers at Lake Conchos)	81.8%	= 100%	127.8%	= 156.0%	80%	= 97.9%
January to June (†5 months—writers at Lake Conchos)	75.8%	= 100%	97.4%	= 128.5%	80%	= 105.6%
October to January, inclusive (4 months—writers at Lake Conchos)	81.8%	= 100%	112.2%	= 137.0%	80%	= 97.9%
October to April, inclusive (7 months—writers at Lake Conchos)	82.5%	= 100%	108.0%	= 131.0%	80%	= 97.1%

* 15 days in January plus all of February plus 9 days in March.

† 15 days in January plus all of February to May plus 3 days in June.

Progressive values for the various periods above are given in Table 89, as worked out from Column (22) of Table 88, as advanced by Mr. Post, and as adopted by the writers at the uniform value of 80 per cent. In working out periods including only parts of months, the monthly values will be weighted in proportion to the fraction of the whole month covered by the observations. Messrs. Duryea and Haehl.

Column (1) of Table 89 is largely copied directly from Column (22) of Table 88, as the most reliable values. The values of Column (3) of Table 89 are from Mr. Post's discussion.* It should be noted that the average of the twelve values for the separate months, is 107.5% of the "year" for Column (1) and 112% for Column (3). Hence, in deriving the comparative percentages of Columns (2), (4), and (6) from combinations of Columns (1), (3), and (5), an attempt was made to correct roughly for such lacks of check, as shown in the examples which follow. It is believed that (even though still only approximate) the values of Columns (2), (4), and (6) are nearer truly comparative than if such corrections had been omitted.

Examples.—

Columns (4) and (6), for Separate Months:

$$\text{Column (4)} = \frac{\text{Column (3)}}{1.12} \div \frac{\text{Column (1)}}{1.075} = \frac{(1.075)}{(1.12)} = 0.96$$

$\times$ Column (3) $\div$ Column (1) $= 0.96 \times 150 \div 74.7 = 193\%$ for January, etc.

$$\text{Column (6)} = \frac{\text{Column (5)}}{1.00} \div \frac{\text{Column (1)}}{1.075} = 1.075 \times \text{Column (5)}$$

$\div$ Column (1) $= 1.075 \times 80 \div 74.7 = 115.2\%$ for January, etc.

Columns (4) and (6), for Progressive Periods:

Column (4) = Column (3) $\div$ Column (1); as $134.0 \div 79.8 = 168\%$ for December to February, etc.

Column (6) = Column (5) $\div$ Column (1); as $80 \div 79.8 = 100.3\%$ for December to February, etc.

Columns (1) and (3), for Progressive Periods:

Column (1)—(Dec. to Feb.).		Column (3)—(Dec. to Feb.).	
Dec.	88.2	Dec.	150.
Jan.	74.7	Jan.	150.
Feb.	94.6	Feb.	150.
Mean	$= 85.8 \div 1.075 = 79.8\%$, etc.	Mean	$= 150. \div 1.12 = 134.0\%$, etc.

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2691–92.

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Column (1)—Jan. to Mar., 2 months (nearly).	Column (3)—Jan. to Mar., 2 months (nearly).
Jan. (15 days) 74.7 × 0.48 = 36.2	Jan. 150. × 0.48 = 72.
Feb. (1 month) 94.6 × 1.00 = 94.6	Feb. 150. × 1.00 = 150.
Mar. (9 days) 85.6 × 0.29 = 24.8	Mar. 108. × 0.29 = 31.3
1.77 months = 155.6	1.77 months = 253.3
Mean for period = 88.0	Mean for period = 143.2
88.0 ÷ 1.075 = 81.8%	143.2 ÷ 1.12 = 127.8%
Column (1)—Jan. to June, 5 months (nearly).	Column (3)—Jan. to June, 5 months (nearly).
Jan. (15 days) 74.7 × 0.48 = 36.2	Jan. 150. × 0.48 = 72.
Feb. (1 month) 94.6 × 1.00 = 94.6	Feb. 150. × 1.00 = 150.
Mar. (1 month) 85.6 × 1.00 = 85.6	Mar. 108. × 1.00 = 108.
Apr. (1 month) 88.6 × 1.00 = 88.6	Apr. 108. × 1.00 = 108.
May (1 month) 60.8 × 1.00 = 60.8	May 108. × 1.00 = 108.
June (3 days) 67.4 × 0.10 = 6.7	June 108. × 0.10 = 10.8
4.58 months = 372.5	4.58 months = 556.8
Mean for period = 81.4	Mean for period = 109.2
81.4 ÷ 1.075 = 75.8%, etc.	109.2 ÷ 1.12 = 97.4%, etc.

It should be noted that in Table 89 the ("Average") and the "Year" (below the Separate Months of both Column (4) and Column (6)) agree quite closely with one another.

The discussion of Subsidiary Conclusion (*b*) now can be completed by the help of Tables 88 and 89.

Column (1) of Table 89 is believed to present fairly well-established values of (*b*), with the weight of 9 pan (pair) years of actual evaporation observations made by Messrs. Grunsky, Lee, and the writers, in three widely separated localities; and all made with 3-ft. square pans and with floating-pans and land-pans all placed in a usual or standard manner. It is not claimed that the values of Column (1) cannot be amended and improved by the addition of other good evaporation records, either past or future. It is believed, however, that the values given are better established than any hitherto presented, and that (until and unless they are replaced by other values still better established) they may be used with a fair degree of confidence as approximate measures of the correctness of other and differing assumed values.

Measured in this way, the values found by Mr. Post at San Diego (and shown in Column (3) of Table 89) do not appear to be justified at other places, either for full years, for separate months, or for any of the progressive periods of from 2 to 7 months included in Table 89, as his values of Column (3) vary from the (present) standards of

Column (1) by from + 93 to — 10% for the separate months, by from + 68 to + 4.5% for the seven progressive periods, and by + 28.8% for the full year. Messrs. Duryea and Haehl.

The only explanation offered by the writers, for the discrepancy between Mr. Post's values and the presumably better established general values of Column (1), is that given tentatively hereinbefore: that his values are "due to the influences of some unknown and unrealized local differences of climate and exposure, as between his land-pans and his floating-pans".

The foregoing comments on Mr. Post's values of (*b*) apply also in the main to Mr. Ledoux' value of Table 87.

As to Mr. Hawgood's opinion (that there are no stable relations between the evaporation depths from floating-pans and those from land-pans), the varying values of Column (1) of Table 89 at first glance seem to confirm that view, but a closer study seems to show that the variations of Column (1) are less than they may appear. For the separate months, the mean of the twelve monthly values is 82.5%, the maximum value is 95.9%, and the minimum value 60.8%, or a variation of from —21.7 to + 13.4 per cent. For the seven progressive periods of from 2 to 7 months, the maximum value is 82.5% and the minimum 70.4%; or the variations from the yearly mean of 76.8% are from — 6.4 to + 7.7 per cent. These variations do not seem great enough to confirm Mr. Hawgood's view, even for parts of years.

The uniform value of 80% adopted by the writers compares with Column (1) as shown by Column (6). For the separate months, Column (5) varies from 92.1 to 141.4% of Column (1) and for the seven progressive periods from 97.1 to 113.7%; or the values of Column (5) vary from those of Column (1) from — 7.9 to 41.4% for the separate months, from — 2.9 to + 13.7% for the seven progressive periods, and, for the full yearly cycle, is 4.2% greater. Hence the uniform value of 80%, assumed by the writers, is not (for the yearly cycle or even for the seven shorter periods) greatly in disagreement with the more carefully worked up values of Column (1).

Subsidiary Conclusion (*c*) *of Table 2.*—This conclusion (that the evaporation depth from a large reservoir is about 62% of that from a 3-ft. pan floating thereon) is that of Professor Bigelow, as interpreted by the writers.

Mr. Lee questions the foregoing statement* as not being a correct interpretation of Professor Bigelow's meaning, and dissents from the writers' statement that:

"* * * it has been recognized more or less generally that the evaporation losses from large reservoirs * * * are materially less than the evaporation depths measured in pans, even when the pans are floating on the reservoir".

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2708–9.

Messrs. Duryea and Haehl. That others have interpreted Professor Bigelow's experiments in this respect in agreement with the writers' interpretation, and that such interpretation is a matter of public record, is shown by the following quotations*:

"Experiments made in 1909-10 by the U. S. Department of Agriculture gave the following figures for the annual evaporation at twenty places in the United States, the evaporating pan being at or very near the surface of the ground or water."

* * * * * * *

"Birmingham, Ala., 4 ft. diameter of pan, floating in reservoir; annual evaporation 51.74 inches."

* * * * * * *

"The evaporation from a pan 2 ft. in diameter is about 75%, that from a pan 4 ft. in diameter is about 50%, and that from a pan 6 ft. in diameter is about 30% greater than the evaporation from a large pond or lake. The above [tabular] figures may be roughly corrected by using these percentages; thus, at Birmingham, Ala., the true annual evaporation is 34.50 in."

From Table 13, it is seen that the foregoing percentages are equivalent to those of Table 2, and to the evaporation depth from a large reservoir, being 62% of that from a 3-ft. pan floating thereon. The Associate Editor of Section 13 of the "American Civil Engineers' Pocket Book" (from which the foregoing quotations are taken) is Mr. Louis A. Fischer, Chief of Division of Weights and Measures, U. S. Bureau of Standards.

Again, the relative evaporation depths from pans and from reservoirs is referred to (though rather indefinitely) by Philip À Morley Parker,† M. Am. Soc. C. E., as follows:

"Modern studies show that the evaporation from the water surface of a large reservoir is considerably less than (usually about $\frac{2}{3}$) that which is observed in ordinary evaporation pans."

(and)

"The later studies referred to on page 740, prove that the absolute magnitude of the evaporation from a free water surface has, until lately, been largely overestimated, and since no actual gaugings showing the loss assumed to exist have ever been recorded, I am inclined to believe that in Temperate Insular climates at any rate, the loss is inappreciable, or even non-existent."

Also, Mr. Hegly in his discussion‡ refers (as a well-known fact) to the smaller evaporation depths from reservoirs than from evaporation pans, though he does not mention whether he intends his statement to apply to land-pans, to floating-pans, or to both.

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* "American Civil Engineers' Pocket Book", p. 1286 of 1st (1911), p. 1256 of 2d (1912), and p. 1256 of 3d (1916) editions.

† "The Control of Water", 1913, pp. 740, 207.

‡ *Proceedings*, Am. Soc. C. E., for May, 1916, p. 787.

As to the statements by Mr. Grunsky and Mr. Lee, that Professor Bigelow's Salton Sea experiments included no observations on floating-pans, and hence can furnish no data showing that the evaporation depth from reservoirs is materially less than that from pans floating thereon, it is shown in the preceding part of this closing discussion, on Subsidiary Conclusion (*a*), that Professor Bigelow's experiments did approximate floating-pan conditions. Also, he did not secure his value of C_2 for a large water surface by direct observation, but Messrs. Duryea and Haehl.

*"By computing with the formula, assuming values of $C_2 = 0.021$, 0.023, 0.025, 0.027, 0.029, and using the observed temperatures of the Salton Sea surface water, it is now probable that the coefficient for a large water surface is $C_2 = 0.024$."

That value is 61.7% of his value, 0.039, for a 3-ft. pan.

This explanation applies also to Mr. Follansbee's discussion of (*c*).†

Aside from whether the writers have interpreted correctly in this respect Professor Bigelow's experiments, much more important questions are: whether any logical reasons can be given why the evaporation depth from pans floating on a reservoir should be materially greater than the evaporation depth from the reservoir itself; and whether such data as are available do or do not show the pan evaporation to be greater.

It seems to the writers that a sufficient reason is that given by Mr. Follansbee,† as follows:

"A contributing factor to the greater evaporation in floating-pans is the wetted strip around the inside of the pan, just above the normal water surface, caused by the wave action within the pan itself. This frequent wetting of the sides of the pan exposes an addtional wetted area on a warm iron surface, and hence causes greater evaporation."

Some additional warm wetted surface must be caused by capillary action, and the waves within the pan and the area of the thin film of water on the warm iron surface must be increased greatly by the effect of the wave action in the reservoir and the resulting oscillatory tipping of the pan, even with small waves in the reservoir.

As to actual data tending to show whether or not the evaporation depth from a pan floating in a reservoir is greater than that from the reservoir itself, the only data known to the writers are those in the paper for Lake Conchos and Salton Sea, and some by Mr. Post and Mr. Whitney in the discussions.

Mr. Post's data relating to Murray Hill Reservoir‡ give the evaporation depth from that reservoir as 107% of that from a floating-pan; but the observations are for only a week, and the pan was floating on

* *Proceedings*, Am. Soc. C. E., for September, 1915, p. 1746.

† *Proceedings*, Am. Soc. C. E., for January, 1916, p. 160.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2699.

Messrs. Duryea and Haehl. La Mesa Reservoir, 5 miles distant. Due to the short duration, the distance of the pan from the Murray Hill Reservoir, and the possible differing climatic conditions at pan and at reservoir throughout the short period, it is not believed that these data can have any weight in determining this question.

Mr. Post's other applicable data are contained in Tables 58 and 59.* Table 58 compares the computed actual monthly evaporation depths from Cuyamaca Reservoir with the evaporation depths from a pan 3 ft. square and 18 in. deep floating thereon. The observations cover a continuous period of 15 months, of which two disconnected months are excluded from the totals by Mr. Post for reasons not stated. The results of Table 58 may be summarized briefly as follows:

MONTHLY EVAPORATION DEPTHS FROM RESERVOIR, AS PERCENTAGES OF THOSE FROM FLOATING-PAN.

	Extremes.		Mean.	
For the 15 months	35% and 118%		77%	
For 13 months only (35% and 36% excluded)	45% and 118%		83%	
Number of months less than 100%	11		9	
Number of months more than 100%	4	15	4	13
Number of months less than 62%	5		3	
Number of months more than 62%	10	15	10	13

Table 59 compares the actual monthly evaporation depths from Sweetwater Reservoir for 28 months (continuous) and from Upper Otay Reservoir for 7 months (not continuous), with the monthly evaporation depths from a pan, 3 ft. square and 18 in. deep, floating on La Mesa Reservoir, 7 miles from Sweetwater Reservoir and 12 miles from Upper Otay Reservoir. The results of Table 59 may be summarized briefly as follows, the percentages being for the "Mean" column of Table 59.

MONTHLY EVAPORATION DEPTHS FROM RESERVOIR, AS PERCENTAGES OF THOSE FROM FLOATING-PAN.

	Extremes.		Mean.	
For the 28 months	3.2% and 127%		80 %	
For 27 months only (excluding 3.2%)	31 % and 127%		82.5%	
Number of months less than 100%	24		23	
Number of months more than 100%	4	28	4	27
Number of months less than 62%	11		10	
Number of months more than 62%	17	28	17	27

It is noticeable that the evaporation depths for the Upper Otay Reservoir, given by Mr. Whitney in Table 74,† do not agree (for 2 of the 7 months) with those given by Mr. Post in Table 59; the depth in Table 74 being 8.0 in. for August, 1914, and 8.0 in. for August, 1915, and those by Mr. Post being 12.06 and 10.0 in., respectively. Accepting Mr. Whitney's values as the more probable and reasonable, and

* *Ibid*, pp. 2700–01.

† *Proceedings*, Am. Soc. C. E., for April, 1916, p. 580.

Messrs. Duryea and Haehl.

correcting the preceding table accordingly, the following values are obtained:

MONTHLY EVAPORATION DEPTHS FROM RESERVOIR, AS PERCENTAGES OF THOSE FROM FLOATING-PAN (CORRECTED).

			Extremes.	Mean.
For 27 months			31% and 121%	78%
Number of months less than 100%	24			
Number of months more than 100%	3	27		
Number of months less than 62%	10			
Number of months more than 62%	17	27		

It is apparent that the distances between pan and reservoirs (7 and 12 miles, in hilly country) make this average relation of 78% far from reliable. This is indicated, also, by the wide range in the monthly values, from 31 to 121 per cent.

The relations given by Mr. Whitney in Table 76,* between the evaporation depths from the Upper Otay Reservoir and those from a 3-ft. square pan floating thereon, for 2½ months, have such wide variations (80% for October, 142% for November, 52% for December, and 87% as the average for the 2½ months), that they cannot be regarded with confidence as reliable measures of this relation.

As to Professor Bigelow's value of this relation at Salton Sea, interpreted by the writers as 62%, it is apparent that Mr. Louis A. Fischer, Chief of Division of Weights and Measures, U. S. Bureau of Standards, made an identical interpretation as early as 1911. The several rough checks given in Table 14 on the 62% value, though pointed out there as merely approximations, and with some uncertainties, still are based on values adopted after some thought by one physicist and two engineers, and are believed to have some corroborative value.

There remain for consideration only the Lake Conchos determinations of the value of (c), summarized in Table 50. As to the pan evaporations at Lake Conchos, they were made only by usual and ordinary methods, but, it is believed (as shown by Mr. Thorpe's discussion), with more care and attention to reliability than is at all usual in most engineering tests for evaporation; and, as representative of the true evaporation depths from the pans during the periods observed, it is believed that they may be accepted safely as at least as accurate as the majority of pan evaporation data accumulated up to the present time, and probably more so. The floating-pans were placed well out from shore, in exposed deep water apparently representative of the greater proportion of the lake; and, during the dry season (when the pan evaporations used were taken), the climatic conditions apparently were very uniform and stable over the area of the lake.

* *Proceedings*, Am. Soc. C. E., for April, 1916, p. 582.

Messrs. Duryea and Haehl. As to the measured evaporation depths from the lake surface itself, worked out in Table 45, the measurements on which these are based also were made with much care as to their reliability.

The inflows to the lake as gauged at Pilar de Conchos and the outflows as gauged below the La Boquilla Dam, were from daily gauge heights in the low-flow season (of a stream not flashy and having drainage areas above the gauging stations of about 7 000 sq. miles), used in conjunction with carefully rated stream sections at the two gauging stations. The sections were re-rated afterward and found to be stable and unaltered, and the current meters (Gurley Price meters) were tested and found not to have changed their ratings. The outflows through the dam also were checked in other ways, as by pipe flow, and the seepage losses were measured carefully by weirs, etc.

The elevations of the lake surface (used in conjunction with its surface areas to estimate the increase or decrease in the volumes of stored water during the 7 months and the included 4-months periods) were taken from monthly tables of the daily gauge heights of lake elevation, which changed very slowly and evenly. The corresponding surface areas of the lake were from carefully prepared curves and tables of areas and volumes, and it is noticeable that, during the 4-month and 7-month periods, the changes of elevation were small, a net fall of only 0.04 m. (1.58 in.) in the 7-month period and a net rise of only 0.32 m. (12.60 in.) in the included 4-month period.

As to the elimination in Table 45 of the rain falling directly on the lake surface, and the substantial uniformity of the rainfalls at the opposite ends of the lake, such uniformity is shown by the comparisons in Table 90.

At both La Boquilla and Pilar de Conchos only a small part of the total yearly rainfall occurs during the 8 dry months, October to May, and about the same proportions at the two places. These facts are shown by Table 91.

Table 91 shows that, during the 12 months, June, 1913, to May, 1914, the rainfall at Pilar de Conchos was only about 10% greater than that at La Boquilla; and, during the 8 months, October, 1913, to May, 1914 (about the period for which the evaporation depth from the lake itself was estimated), only about 16% greater and 2.2 in. more. These close agreements and the small differences in the monthly rainfalls of Table 90 at the two places show the small probability of any material error arising in the estimation of the average rainfall on the lake as the mean of the rainfalls at La Boquilla and at Pilar de Conchos.

Another important element in Table 45 is the assumption that there were no accessions to the lake storage during the 7 months, October, 1913, to April, 1914, except the gauged inflow of the main river past Pilar de Conchos and the rain falling directly on the lake surface. That assumption seems justified, for several reasons.

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TABLE 90.—COMPARATIVE MONTHLY RAINFALLS, IN INCHES, AT LA BOQUILLA AND AT PILAR DE CONCHOS, 25 MILES APART.

(See Figs. 1 and 3.)

Month.	1912.		1913.		1914.		1915	
	La Boquilla.	Pilar de Conchos.	La Boquilla.	Pilar de Conchos.	La Boquilla.	Pilar de Conchos.	La Boquilla.	Pilar de Conchos.
January...	*0.28	Trace.	0.35	0.20	0.00	Trace.	0.51	1.04
February..	0.00	"	0.46	0.69	0.06	0.08	Trace.	0.06
March.....	0.00	"	Trace.	0.00	1.10	0.31	0.24	0.37
April......	0.00	0.43	0.37	0.04	0.00	Trace.	0.04	Trace.
May.......	1.14	Trace	0.02	Trace.	1.26	1.02	0.00	Trace.
June.......	0.51	1.59	3.37	3.21	4.70	8.54	Trace.	0.41
July.......	2.05	1.78	2.59	1.73	3.15	3.60	4.36	4.42
August....	2.30	3.61	1.75	6.08	4.82	3.17	9.56	6.77
September.	2.53	4.08	4.21	3.09	2.42	4.92	2.72	3.99
October...	0.85	0.98	0.18	1.22	2.52	1.08	1.10	0.00
November.	0.30	0.49	1.61	1.10	2.22	1.77	0.00	0.00
December.	0.26	0.28	0.12	0.28	1.14	1.14	Trace.	0.08
Year.......	10.22	13.24	15.03	17.64	23.29	25.63	18.53	17.14

* The rainfalls were measured and recorded in millimeters and half-millimeters, and reduced for this table at the rate of 1 in. = 25.4 mm.

TABLE 91.—COMPARATIVE DRY-SEASON RAINFALLS, IN INCHES (OCTOBER TO MAY, INCLUSIVE), AT LA BOQUILLA AND AT PILAR DE CONCHOS.

Rainfall year.	La Boquilla.			Pilar de Conchos.		
	12 months.	June to September.	October to May.	12 months	June to September.	October to May.
1912–13.........	10.00	7.39	2.61 = 26%	13.74	11.06	2.68 = 20%
1913–14.........	16.25	11.92	4.33 = 27%	18.12	14.11	4.01 = 22%
1914–15.........	21.76	15.09	6.67 = 31%	25.69	20.23	5.46 = 21%
Mean......	16.00	11.47	4.53 = 28%	19.18	15.13	4.05 = 21%

Rainfall year.	12 months. La Boquilla ÷ Pilar = Percentage.	8 months. October-May. La Boquilla ÷ Pilar = Percentage.
1912–13.........	10.00 ÷ 13.74 = 73%	7.39 ÷ 11.06 = 67%
1913–14.........	16.25 ÷ 18.12 = 90%	11.92 ÷ 14.11 = 84%
1914–15.........	21.76 ÷ 25.69 = 85%	15.09 ÷ 20.23 = 75%
Mean......	16.00 ÷ 19.18 = 83%	11.47 ÷ 15.13 = 77%

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First, the region is a semi-arid one, with no small running streams throughout the dry season, when water is flowing only in large rivers like the Rio Conchos. This condition is a usual and general one, and such arroyos as lead into the lake between Pilar de Conchos and La Boquilla are dry, except during the heavy rains of the rainy season. This condition was observed by Mr. Thorpe and his assistants at frequent intervals, and even by one of the writers (on a trip from La Boquilla to Pilar de Conchos and return, in March, 1914). Also, any material inflows from those arroyos carry with them considerable silt, and thus increase quickly and noticeably the turbidity of the lake.

Second, the drainage areas of the arroyos leading into the lake from the north and south are narrow and small, and can easily absorb all such small and infrequent rainfalls as occur during the dry season. This is evident from the comparative data of rainfall and run-off as follows:

From Tables 97 and 98, and more detailed data, the total stream flow of the Rio Conchos during the whole year, 1913, was only a very small proportion of the rainfall on its drainage areas:

From drainage area above its mouth only about 4.5 per cent.
" " " " La Boquilla " " 6.8 " "

The greater part of these yearly run-offs occurred during the rainy and flood season, and nearly all of that measured at La Boquilla came from the (about) 7 000 sq. miles of drainage area up stream from the lake, and very little of it from the few square miles of tributary area abutting on the lake; and, during the dry season, the percentage of run-off from those abutting areas must have been practically nothing.

During the 12 months, May, 1913, to April, 1914, the total measured run-off at La Boquilla (including the floods of May to September, 1913), was equivalent to an average depth from the (about) 7 000 sq. miles of drainage area of only about 1.11 in.; of which only about 0.12 in. (about 11%) ran off during the 7 months, October to April. It is believed that all of this 0.12 in. was furnished from the large area up stream from Pilar de Conchos, and practically none of it from the two small narrow drainage areas at the north and south sides of the lake, between Pilar de Conchos and La Boquilla Dam.

From Table 6, the normal or mean rainfall at the lake during the 7 months, October to April, amounts to only about 2.75 in., or about 23% of the mean yearly rainfall. From Tables 45, 90, and 91, the rainfall at the lake during the 7 months, October, 1913, to April, 1914, was only about 3.0 in. From Table 90 and daily rainfall records, the infrequent rainfalls of the dry season are widely distributed over the 7 months, with ample opportunity for the ground to dry out between the rains, and hence with very little chance for those rains to contribute to the run-off or stream flow.

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As the result of 7 years of very careful rain and stream gaugings, by the writers, of a California stream having rainfall and seasonal conditions quite similar to those of the Rio Conchos (the Coyote River, of about 200 sq. miles drainage area), it was found that there were no stream flows contributed by the scattered autumn rainfalls of a new rainy season until after the first 2 to 10 in. (usually from 5 to 8 in.) of rain had fallen. This condition was confirmed by similar gaugings, of 1 to 4 years each, on six other streams in the same general region, the rainfalls, before stream flows resulted, being there 1.3 to 13 in., usually from 5 to 10 in. The average regional yearly rainfalls on the Coyote drainage area varied from about 19.0 to 35.4 in. during the 7 years, and on the other six streams from about 18.3 to 50.0 in. The drainage areas of all the seven streams are in general rough and mountainous, and the year's rainfall nearly all occurs in a rainy season (about October to April) of about 6 months.

From what has been said it is apparent that:

The stream flows at La Boquilla for the calendar year, 1913, aggregated only about 6.8% of the tributary rainfall, most of this stream flow occurring in the rainy or flood season of June to September, and nearly all of it coming from the large tributary area (about 7 000 sq. miles) above Pilar de Conchos;

During the 12 months, May, 1913, to April, 1914, the total stream flow or run-off at La Boquilla was equivalent to only about 1.11 in. depth on the tributary drainage area, of which only about 11% (about $\frac{1}{8}$ in.) occurred during the 7 months, October to April;

In those 7 months only about 3 in. of rainfall occurred at Lake Conchos, in scattered rains;

Under similar conditions, on similar streams in California, usually more than 5 in. of scattered rains fell in the autumn before any of it began to appear as stream flow; and

From occasional visual observations along the lake and constant observations at the dam, there is believed to have been no material inflow into Lake Conchos between Pilar de Conchos and the La Boquilla Dam during the 7 months, October, 1913, to April, 1914.

About the only other elements which enter into the Lake Conchos check of the 62% value of Subsidiary Conclusion (*c*), are the reduction by 20% of the observed evaporation depths from the land-pans to bring them to assumed corresponding depths from floating-pans, and the expansions into full years of the (about) 5 months' pan observations and of the 7 months' lake observations. As to the 80% relation, that has been discussed already under (*b*), and it is believed to be fairly well established that the evaporation depths from floating-pans are in gen-

Messrs. Duryea and Haehl. eral considerably less than those from near-by land-pans of the same size, and probably about 80% thereof. As to the expansions from part year to full year, they were each made by two methods, (*a*) and (*b*) (B_a and B_b for the pans, and C_a and C_b for the lake), the two methods checking each other closely for yearly evaporation depths; and, as the periods for pan and lake observations were largely coincident (January to June for pans and October to April for lake), and as the same methods of expansion were used for both, the correctness of their comparative yearly values (or the value used to check Subsidiary Conclusion (*c*)) should to a large degree be unaffected by the absolute correctness of the methods of expansion used and of the resulting yearly values.

In view of all the additional explanations of Subsidiary Conclusion (*c*) which have been given, at the very least, it is believed to be a reasonable probability that the evaporation depths from large reservoirs are much smaller than those from evaporation pans floating thereon, and for 3-ft. pans probably only about 62% as great. It is acknowledged, however, that this and some others of the writers' conclusions are shown by some of the discussions to be open to more or less question, which can be settled conclusively only by more complete, exact, and reliable future data. In the meantime, however, it is felt that Subsidiary Conclusion (*c*) may be given at least tentative acceptance as expressive of the best data as yet available.

The remaining subsidiary conclusions of the paper are that the evaporation depths at different places throughout the Great Plateau increase almost directly with (*d*), increases in the mean temperature, and (*e*), increases in the elevation above sea-level, as stated in Table 2 and shown by Fig. 4. This discussion of (*d*) and (*e*) will be more or less a combined one, and also will be briefer than the foregoing part of this closure.

It is apparent from a study of the paper that (*d*) and (*e*) are based entirely on data of pan evaporations made at six stations, and not at all on Piche evaporimeter records and evaporation depths calculated therefrom. The Piche records presented in the paper were considered for use in conjunction with the pan data, but were rejected as unreliable for such uses. Many interesting comments on Piche records are given by Messrs. Lee, Follansbee, Meyer, Comstock, Grunsky, and Hegly, all of whom seem to agree on the unreliability of Piche records as measures of absolute evaporation depths; however, no actual use was made of them in the paper.

In considering (*d*) and (*e*), it should be remembered that they were stated repeatedly by the writers as applicable only to the evaporation relations between places on the Great Plateau, or between places where the climatic conditions other than mean temperature are quite similar. Apparently, the writers did not emphasize this point to the satisfaction

of Mr. E. F. Chandler,* though they intended to emphasize it and thought they had done so. Messrs. Duryea and Haehl.

Conclusion (*d*) seems to be agreed with in a general way (at least qualitatively, even if not quantitatively) by several of those who discuss it. Mr. Chandler shows by Fig. 16† that, for a period of 10 years in North Dakota, with observed values for 71 months, the observed evaporations are found

"* * * to be satisfied fairly well from temperatures 35 to 75° Fahr. by the 'straight-line' curve representing the equation,

$$E = 0.135\ T - 4.00,$$

in which E is the evaporation, in inches, during the month, and T the mean temperature of the month, in degrees, Fahrenheit."

It also is stated by him that, if the values of Fig. 4 and Fig. 13‡ are applied to the mean monthly temperatures of the Red River Valley of North Dakota, the corresponding equation is

$$E = 0.20\ T - 10.00.$$

As was to be expected, this differs widely from his equation of North Dakota evaporations and mean temperatures.

Mr. Post shows, by Figs. 17 and 18,‡ that for the climatic conditions near San Diego, Cal., the relations between evaporation, mean temperature, and elevation above sea level may be represented fairly well (neglecting all the other elements of the climate) by straight lines or by lines of light curvature approximating them.

Mr. Lee says§:

"The authors' analysis of this subject [(*d*)] is very interesting and suggestive, and the results are of value within the general region to which they can be applied and when evaporation records are not available."

As to (*e*), he says:

"The writer would make much the same comment * * * as he has on [(*d*)]."

Mr. Robert Follansbee‖ seems to accept the writers' Conclusion (*d*), in so far as it relates to the southern part of the Rio Grande drainage, but to find it not applicable to some other regions which he has investigated, in this respect. He says:

"The writer was especially interested in the simple relations between evaporations and temperature for the records in the southern part of the Rio Grande drainage. To determine whether a similar relation

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2688–89, 2691.

† *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2689–90.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2692 and 2696.

§ *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2709.

‖ *Proceedings*, Am. Soc. C. E., for January, 1916, pp. 160–163.

Messrs. Duryea and Haehl. exists for the upper part of the Rio Grande drainage at an elevation of 7 200 ft., the records near Santa Fé were investigated, [as] compiled by the U. S. Geological Survey.

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"* * * Fig. 21 shows that the points do not lie on or near a single straight line, as would be the case if the simple relation between monthly evaporation and temperature obtained.

* * * * * * *

"* * * From these records, it is evident that other factors than temperature—such as wind velocity and relative humidity—influence evaporation to such an extent in the upper part of the Rio Grande drainage that it is impossible to determine evaporation [there] with any degree of accuracy from temperature records alone.

"An investigation of evaporation records in the southwestern part of Oklahoma was made in order to determine whether a simple relation obtained between temperature and evaporation in that section of the country.

* * * * * * *

"The plotting of the monthly evaporation and mean air temperature, Fig. 22, shows that the relation between the two at this point is complicated to a great extent by the other evaporation factors, making it impossible to determine evaporation [there] from air temperatures alone."

Mr. Grunsky states that some years ago he himself pointed out:

"* * * the preponderating influence of temperature on evaporation * * * and * * * the use of mean monthly temperatures as a guide in approximating the evaporation from a water surface such as that at Salton Sea was illustrated. This article* was prepared by the writer in order to show that, throughout regions in which climatic conditions are similar, it may be assumed that errors due to more or less wind movement in one locality when compared with another, and those due to small differences in relative humidity and other similar causes, may be neglected, and, [that] for all preliminary engineering purposes, evaporation from an open water surface may be determined from mean monthly temperature.

"It will be apparent, however, that this can only be done after the relation between the mean monthly temperature and the rate of evaporation at one or more selected points during the calendar months has been determined experimentally."

Mr. Grunsky thus agrees that the evaporation does increase as some function of the mean temperature (as is almost self-evident), and that the influence of mean temperature is "preponderant"; but he does not agree with the writers' Conclusion (*d*) as to a simple "straight-line" relation.

As to the straight-line relation: the writers must admit that it is somewhat forced, and is only approximately true; and that, in view of the few data used by them as a basis for it, and of the uncer-

* *Engineering News*, Vol. 60, August 13th, 1908, p. 163.

Messrs. Duryea and Haehl.

tainties of some of these, which have been pointed out, the straight-line relation does not seem well proven.

However, Mr. Grunsky's Figs. 28, 29, and 30* show that, for mean monthly temperatures greater than 50 to 60° Fahr., the curves of temperature evaporation relation are light ones and not great departures from straight lines, even for the long, careful, and widely separated evaporation observations at Kingsburg, Chestnut Hill, Lee Bridge, and Owens River; and Table 42 shows that the evaporations observed at Lake Conchos differ but little from those estimated by assumed straight-line temperature-elevation-evaporation relations. However, this close agreement, of course is partly dependent on some of the assumptions and data which have been criticized adversely by some of those discussing the paper.

In connection with Conclusion (*d*), it is of interest to note that in Table 71† Mr. Grunsky has estimated the normal yearly evaporation depth from Salton Sea by using the monthly mean temperatures there in conjunction with the Kingsburg evaporation-temperature curve (presumably Fig. 28‡), and neglecting all other elements of the two climates; and gets as a result a probably normal yearly evaporation depth from Salton Sea of 6.24 ft. (or a little less), or about 74.8 in. From Table 14, various estimates of the yearly evaporation from Salton Sea are from 67 to 73.7 in., or in fairly close agreement with Mr. Grunsky's estimated value of 74.8 in.

In Table 71 there are no normal mean monthly temperatures at Salton Sea below 50° Fahr., and only 3 months (December, January, and February) appreciably below 60°; and the light curve of Fig. 28 is approximately a straight line above 60°, and only a little farther from it above 50 degrees. Hence it appears probable that, as between Kingsburg and Salton Sea, the yearly evaporation may be estimated with a fair degree of approximation by a "straight-line relation" of evaporation to mean temperature, neglecting all the other elements of the two climates. Salton Sea is about 300 miles from Kingsburg, and is about 200 ft. below sea level, or about 500 ft. lower than Kingsburg. The two places are separated by much mountainous country, and presumably have considerable differences of climate.

This close check may be merely an accidental coincidence; but it appears to the writers to have some weight (even though indefinite), as indicating the comparatively small influence on evaporation of most elements of climate other than mean temperature, and the approximate "straight-line relation" between evaporation depth and mean temperature.

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* *Proceedings*, Am. Soc. C. E., for April, 1916, pp. 565–567.

† *Proceedings*, Am. Soc. C. E., for April, 1916, p. 574.

‡ *Proceedings*, Am. Soc. C. E., for April, 1916, p. 565.

Messrs. Duryea and Haehl.

Others who discuss Subsidiary Conclusion (*d*) are Messrs. Comstock, Horton, and Ledoux. Mr. Comstock's study* of the mean departures of the observed monthly evaporations at El Paso, Albuquerque, Carlsbad, and Elephant Butte from their respective curves is instructive, and weakens those data somewhat as a valid basis for Conclusion (*d*). However, though the mean departures of 12 to 15% are in a sense large, as related to values in climatology they are not unduly large. For instance, in Tables 28 and 29 the mean departure of the 11 yearly values of pan evaporation in the Santa Clara Valley is 11%, of the 6 yearly values at Lake Tahoe 8%, and of the 11 Emdrup values 6%, with maximum departures of 25, 16, and 14%, respectively; and, for the 16 years' evaporation records at Boston, the maximum departure was 13 per cent. The three evaporation records just cited are believed to be as reliable, at the very least, as is usual for data of this class; and the mean departures of 12 to 15% pointed out by Mr. Comstock are but small compared with the greater departures usual in records of yearly rainfall and stream flow. The 12 to 15% mean departures must be admitted to weaken Conclusion (*d*) as dependent on those data; still, they are felt to give some weight to that conclusion, though (*d*) is admitted to be more roughly approximate than was realized.

Discussing Subsidiary Conclusion (*d*), Mr. Robert E. Horton says†:

"It has long been known that measured evaporation losses from water surfaces could be represented graphically in a fairly satisfactory manner in terms of temperature alone as the independent variable.

* * * * * * *

"For the purpose of determining the relation of evaporation to temperature, considering the latter as the only independent variable. the writer has tabulated the experimental data for Albuquerque, N. Mex., from the records of the Hadley Climatological Laboratory, as appearing on Plate XXXI, and has computed therefrom the correlation coefficient. * * * The computations are given in Table 78‡, and indicate a correlation coefficient, 0.92 in this instance. The probable error of a single observation by the usual formula is 0.0189. If there is perfect correlation between two quantities, the correlation coefficient should be unity. If there is no correlation, it would be zero. If the correlation coefficient is five to six times as great as the probable error and is also greater than one-half or two-thirds in absolute value, it indicates a considerable degree of correlation. This calculation appears to indicate that evaporation in the long run may be treated as though it were a function of temperature alone at a given locality. It is true, however, that in any individual period, as for a given month or year, the evaporation is very profoundly modified by other factors, such as variation in the wind velocity and vapor pressure in the air."

* *Proceedings*, Am. Soc. C. E., for March, 1916, p. 394.

† *Proceedings*, Am. Soc. C. E., for May, 1916, pp. 790–92.

‡ *Proceedings*, Am. Soc. C. E., for May, 1916, p. 792.

Mr. Ledoux says*: Messrs. Duryea and Haehl.

"In 1888 and 1889 the writer made weather observations, which included the measurement of evaporation on a water surface containing about 25 acres, in the Alleghany Mountains.

* * * * * * *

"Up to that time, the writer was under the impression that the evaporation from water surfaces was more directly related to relative humidity than to any other factor, but one month's observations absolutely dispelled this belief.

"The final conclusions were that evaporation depends almost entirely on the temperature and the wind, and has very little relation to humidity, even where the relative humidity varies between 70 and 95%; * * *

* * * * * * *

"The writer is under the impression that the evaporation from a water surface is affected materially by humidity where the relative humidity is less than 70 per cent. * * *

" * * * that land gauges give the same result as floating gauges, provided the temperature of the water in the evaporating vessel is kept the same as that of the water in the reservoir; that a gauge 6 in. in diameter will show as much evaporation as one 18 in. in diameter; that it is important that the evaporating vessel be kept full, so as to get a complete water exposure; * * *

"The evaporating vessel was kept as full as possible, say, within ½ in. of the top."

The conclusions of Mr. Ledoux are of great interest, and seem to show the preponderating influence on evaporation of temperature and the small influence of humidity, and thus to strengthen (*d*) somewhat. Some of his conclusions are opposed to the rather general beliefs of other engineers, however, and, in view of this, it is regretted that he did not present the data on which they were based.

His Fig. 31† is of much interest as showing the very great increase in the evaporation depth from increasing the temperature of the water in the evaporating vessel while the air temperature is constant. However, this, of course, is an unnatural condition, as in Nature the temperature of exposed water bodies must follow that of the air, up and down, more or less closely, though with considerable "drag", and with less widely separated extremes of temperature.

It is noticeable that the curve of Fig. 31 is of rather light curvature between temperatures of 80 and 110°, and could be represented there fairly well by a single straight line.

His conclusion that the evaporation depth from small vessels is no greater than that from larger ones is not only opposed to the results of Professor Bigelow's Salton Sea observations, but also is opposed to the natural and very probable influence of the rim conditions which

* *Proceedings,* Am. Soc. C. E., for May, 1916, pp. 794–96.

† *Proceedings,* Am. Soc. C. E., for May, 1916, p. 795.

Messrs. Duryea and Haehl. have been referred to hereinbefore, since the rim influence necessarily must increase the evaporation depth as the size of the evaporating vessel decreases. Keeping the vessels filled almost to their rims, as he recommends, of course will lessen the influence of the rim conditions on the evaporation depth; but, under natural exposed conditions (and especially with pans floating in reservoirs), it is hard to see how pans can be kept so completely filled without much risk of frequently vitiating the record because of the water slopping in and out of the pan from wind and from wave action.

All the evaporation tests given by Mr. Ledoux appear to have been made in vessels so small as to be outside the class of evaporation pans used for practically all recorded observations, which makes his results of doubtful applicability for combinations and comparisons with evaporation records secured from the usual larger pans.

As to Subsidiary Conclusion (*e*), Mr. Grunsky says*:

"The writer believes that the rate of evaporation in relation to mean monthly temperature increases with elevation in some measure, as shown by the authors on Table 17. It is reasonable to expect this, not only because the temperature at which water boils falls with increasing altitude, but, also, because the temperature range, particularly the diurnal range, ordinarily increases with altitude. According to the evaporation law, the mean monthly rate of evaporation will be greatest at that place which shows the greatest temperature fluctuations, because each degree of temperature above the mean produces more evaporation than each degree below the mean.

* * * * * * *

"Although it may be admitted that, for the same mean monthly temperature, the evaporation is greater at high than at low altitudes, the law of this increase is not to be regarded as proven by the data presented in the paper, and Conclusion (*e*) * * * should not be accepted without further verification."

Mr. Grunsky's suggestion of the greater evaporation depths caused by temperatures above than by those below the mean, is illustrated very clearly by Fig. 31.† His statement that the writers' Subsidiary Conclusion (*e*) is not to be regarded as proven by the data presented by them in the paper seems to be warranted, especially in view of the discussion of (*e*) by Mr. Meyer, who points out that some of the differences of evaporation between the Texas and New Mexico stations, assumed by the writers to be due to differences of elevation, as well may be ascribed to differences in their probable humidities.‡

Referring to Mr. Meyer's observation that from Fig. 4 apparently there would be no evaporations at places on the Great Plateau with

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* *Proceedings,* Am. Soc. C. E., for April, 1916, pp. 573, 571.

† *Proceedings,* Am. Soc. C. E., for May, 1916, p. 795.

‡ *Proceedings,* Am. Soc. C. E., for February, 1916, pp. 233–35, 244–47.

Messrs. Duryea and Haehl.

Altitudes about 3 000-4 000 ft. and mean temperatures below 30° Fahr.
" " 2 000-2 500 " " " " " 40 "
" below 1 000 ft. " " " " 45 "

This certainly is a serious defect in the diagrams, if their curves are assumed as producible to such low mean temperatures at such low altitudes. However, the diagrams as published are restricted to lower limits of 40° and 4 800 ft., and 45° and 4 000 ft., and to extremes of 600 and 5 000 ft. altitude, 40° and 90° mean temperature, and 2 and 12 in. monthly evaporation (in 3-ft. floating-pans); and no surmises are made in Fig. 4 as to evaporation depths beyond such limits.

Incidentally, it is apparent from Table 85 that there are almost no mean yearly temperatures (irrespective of altitude) lower than about 50° Fahr. at any of the nineteen places there tabulated, and only two places that low (50° and 48.9°); and even the January mean temperatures are as low as 40° Fahr. at only six of the nineteen places. Of course, there must be some evaporation at 40° and even at still lower temperatures; but it must be small and of little importance as affecting the total yearly quantity.

However, Mr. Meyer's discussion does throw some doubt on the influence of altitude in itself (apart from humidity, etc.) on evaporation depth, and the writers cannot but assent to his conclusion, that*:

"* * * records of relative humidity and wind velocity, combined with records of temperature, afford a far more accurate and reliable basis for estimating evaporation from reservoirs than Fig. 4."

They still believe, however, that altitude should be included as one of the elements influencing evaporation.

Mr. Comstock, though dissenting from the writers' Subsidiary Conclusion (*e*), seems to assent to their claim that evaporation depth increases in some manner with increases of elevation above sea level. In discussing (*e*), he says†:

"* * * Professor Bigelow's failure to find a barometric term [in his equation for evaporation depth] * * * is at variance with experience and experiment.

"In 1789, H. B. de Saussure made comparative observations * * * from which he concluded that, 'other things being equal, a lowering of the pressure of the air by approximately a third makes the quantity of evaporation more than twice as great'.

"Numerous laboratory experiments have shown beyond question that the air opposes a mechanical obstacle to the escape of liquid particles in the form of vapor, and that this obstacle is greater at high than at low pressures.‡ It has been usual to introduce the barometric pressure in such a way as to make the rate of evaporation inversely proportional to the pressure. This is arbitrary, and, although

* *Proceedings*, Am. Soc. C. E., for February, 1916, p. 246.

† *Proceedings*, Am. Soc. C. E., for March, 1916, p. 400.

‡ Hence greater at low than at high altitudes.

Messrs. Duryea and Haehl. perhaps sufficient to cover all natural conditions, is certainly not correct, as it would result in an infinite rate of evaporation in a vacuum, no matter what the temperature. However, if it is even approximately correct, the relation sought by the authors between evaporation and altitude above sea level must be very complex, because it contains implicitly the relation between altitude and barometric pressure.

"The authors have not established any explicit relation between altitude (or barometric pressure) and evaporation, but have put forward a double relation involving altitude, monthly mean temperature, and evaporation. Since, for reasons already given, the temperature-evaporation relation must be rejected, the altitude-temperature-evaporation relation falls with it."

Mr. Comstock's reference to Conclusion (*e*), as being "clouded by the intimate admixture of the assumed evaporation-temperature relation * * * by a double relation involving altitude, monthly mean temperature, and evaporation", hardly seems justified. Irrespective of the validity of (*e*), it is apparent from an inspection of Diagram (*b*), Fig. 4, that especial care was taken to keep the supposed independent influences of elevation and of temperature separated and simplified, by showing the separate effects of altitude at many different temperatures. After considerable thought, no better way could be devised to do this than by Diagram (*b*) of Fig. 4.

In final comment on Subsidiary Conclusions (*d*) and (*e*), it is felt by the writers that they still may be regarded as at least first approximate expressions of probable general relations—even though, in the discussions, some valid and important objections to (*d*) and (*e*), and to their underlying data and methods, have been raised. It is admitted that, as yet, (*d*) and (*e*) are open to more or less question, and that more extended and more accurate data are desirable; but, notwithstanding the admitted faults and doubts, it is felt that the amenability of evaporation-temperature-elevation data to expression in such diagrams as Figs. 4 and 13 (Texas and New Mexico data), Figs. 17 and 18* (San Diego data), and Fig. 16† (North Dakota data, one elevation only), in conjunction with some of the various opinions quoted, make Subsidiary Conclusions (*d*) and (*e*) still worthy of further consideration and investigation.

There remain for consideration various minor points mentioned in the discussions; and the discussions relating to the Principal Conclusion of the paper, the probable yearly evaporation depth from Lake Conchos.

The data of evaporation near Morelia, Michoacán, Mexico, furnished by Mr. Mathewson‡, are of much interest as a check on the appli-

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2692, 2696.

† *Ibid.*, p. 2690.

‡ *Ibid*, pp. 2687–88.

cability of Fig. 4. From and through Mr. Mathewson, the following additional data were furnished to the writers: Messrs. Duryea and Hachl.

"The rain gauge at Morelia had a diameter of 0.226 m. (8.90 in.). I am under the impression that the evaporimeter (evaporating vessel) was of that diameter, but am not sure. Only one evaporimeter was used, a land one located at Morelia with its bottom and sides protected by earth and sod; and the evaporation record secured from it was from May, 1908, to May, 1912, a period of 4 years.

"We observed the farm reservoir about a month and a half, at a time of year when evaporation was high, near the end of the dry season of 1911, I think in April and May. During that period the evaporation from the farm reservoir was only 52% of the coincident evaporation from the land evaporimeter at Morelia. However, the 52% obtained was applied to the evaporimeter data of a drier year, 1909, the year of highest observed evaporation. We used no other data in arriving at a value for evaporation depth from reservoirs".

TABLE 92.—Observed Mean Monthly Temperatures Outside of Botello Power-house (Altitude about 6 560 ft.) near Morelia, Michoacán, Mexico, for 1915; Also, Corresponding Monthly Evaporation Depths from Diagram (*b*), Fig. 4.

Month of year 1915.	Observed mean temperature, in degrees, Fahrenheit.	Corresponding monthly evaporation from 3-ft. floating-pans (as read from Diagram (*b*), (Fig. 4), in inches.
January	* 55.2	7.37
February	55.8	7.50
March	60.0	8.38
April	65.1	9.48
May	71.4	10.43
June	71.0	10.35
July	67.8	9.80
August	66.5	9.62
September	64.5	9.19
October	59.0	8.17
November	57.8	7.92
December	54.8	7.28
Sum	748.9	105.49 in. for year.
Mean	62.4	8.80 in. per month.

* January, 1916 = 57.4° Fahr.

Observed mean monthly temperatures outside of the Botello power-house ("about 4 miles from the farm reservoir observed and a long day's horse-back ride from Morelia") were furnished through the kindness of Mr. Mathewson (see Table 92). He states that as between Morelia and the power-house "there is little if any difference in altitude (about 2 000 m. or 6 560 ft. above sea level) or in climate, and other conditions are similar". To Table 92, for use hereinafter, are added the monthly evaporation depths corresponding to its

Messrs. Duryea and Haehl. monthly mean temperatures, as read off from the original larger scale drawing of Diagram (*b*), Fig. 4, extended by straight lines to altitude 6 560 ft.

The conclusion arrived at by the engineers of the Botello power-house was that the evaporation depth from their reservoirs would have been 1.72 m. = 5.64 ft. = 67.7 in. for 1909, the year of greatest evaporation among the 4 years observed by the evaporimeter at Morelia.

Morelia (not far from the proposed reservoirs) is near the southern end of the Great Plateau, about 600 miles in an air line from La Boquilla.

From Table 92 and Fig. 4, the probable evaporation depths at the Botello power-house in 1915 should have been (from 3-ft. floating-pans) about 105.5 in. for the year, or an average of about 8.80 in. per month. As a check, from Fig. 4 the evaporation depth at altitude 6 560 ft., for a mean temperature of 62.4° Fahr. (the altitude and mean temperature at the Botello power-house), is 8.88 in. per month, or about 106.6 in. per year.

The value of, say, 106 in. per year, multiplied by the 0.62 adopted by the writers as Subsidiary Conclusion (*c*), gives a corresponding evaporation depth from reservoirs near Morelia, Mexico, for 1915, as 65.7 in., as compared with the 67.7 in. adopted there by the engineers from local observations of evaporation, and for 1909, stated to have been the year of greatest evaporation in the 4 years, 1908-11, which were observed (and perhaps greater in evaporation than 1915).

Of course, the apparently close check (of 65.7 in. for 1915 with the 67.7 in. adopted for 1909) may be merely accidental, but, at the least, it does not weaken the writers' statement in the paper, that, in general, fair approximations to evaporation depths at places on the Great Plateau may be read off directly from Fig. 4, without other data than mean temperatures and altitudes.

Mr. Mathewson seems to agree with the writers' belief as to "the almost complete absence of meteorological data in Chihuahua". Mr. Horton calls attention to many evaporation data there and elsewhere in Mexico,* and is to be congratulated on his knowledge of and possession of such little known data. Their existence was unknown to some well-known engineers who had done important hydraulic work in Mexico, and of whom the writers inquired, and is believed to have been unknown to most American engineers.

However, since the evaporation pans used for these Mexican observations were only 8.86 in. in diameter and only 4 in. deep, and were on the roofs of houses and in corridors, it is not felt that these data are of much value to engineers as showing absolute depths

* *Proceedings,* Am. Soc. C. E., for May, 1916, pp. 792–93.

of evaporation, or in any except comparative ways, such as those mentioned by Mr. Mathewson and by Mr. Ledoux.* It is felt that observations conducted with such care, in pans so small and so far outside the range of sizes used almost universally for observations of evaporation, show much wasted effort, though, of course, they are of some value for comparative purposes, when data from larger pans, of usual size, are not in existence. Messrs. Duryea and Haehl.

Mr. Mathewson's determination of the evaporation depth from the farm reservoir as 52% of that from the small land evaporimeter is of little interest, aside from the local use made by him. If Subsidiary Conclusion (*b*) should hold true for such small vessels, which is very doubtful, then the evaporation depth from the farm reservoir was $(52 \div 0.80) = 65\%$ of that from an 8.9-in. evaporimeter floating on it. However, no confidence is felt in the applicability of (*b*) to such small vessels, so far outside the range of sizes usually observed.

Mr. Chandler's data and discussion of observed pan evaporations in North Dakota†; Mr. Follansbee's evaporation data in Oklahoma‡; Mr. L. R. Jorgensen's conclusion as to the evaporation depth from Silver Lake, Mono County, California, as 54 in. per year§; and Mr. Hegly's data of evaporation in Northern Africa and in France‖, are all of much interest and value, as easily accessible data of evaporation are rather meager.

Mr. Meyer presents interesting and valuable matter relating to Piche evaporimeter observations, and to Russell's formula and evaporation table, etc.¶ Figs. 23 to 25 compare the Russell and Duryea-Haehl curves of monthly evaporation and mean temperature, and show them to disagree more or less with each other, as mentioned by him; but still show a rough general agreement in form, both being usually of light curvature, approximately parallel to each other, and not greatly removed from each other in values. Also, some of these curves are for places not on the Great Plateau.

Plate III,** showing contours of elevations and values of relative humidities for many places on the Great Plateau, is of much value, as is his pointing out the excessive humidity of Pike's Peak, compared with that of Fort Grant, about 9 000 ft. lower in altitude, etc.

Mr. Comstock's discussion of the Bigelow formula and of the probable effect of winds on the vapor blanket†† is of much interest, especially his quotations from the writings of Professors S. P. Langley

* *Ibid*, pp. 794–96.

† *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2688–91.

‡ *Proceedings*, Am. Soc. C. E., for January, 1916, pp. 162–63.

§ *Proceedings*, Am. Soc. C. E., for January, 1916, pp. 163–64.

‖ *Proceedings*, Am. Soc. C. E., for May, 1916, pp. 787–90.

¶ *Proceedings*, Am. Soc. C. E., for February, 1916, pp. 233–47.

** *Proceedings*, Am. Soc. C. E., for February, 1916, p. 246.

†† *Proceedings*, Am. Soc. C. E., for March, 1916, pp. 383–89, 396–98.

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and Cleveland Abbe. Mr. Comstock is in error, however, in assuming that the writers made any use of, or gave any consideration to, the Bigelow formula, other than by accepting his relative values of the coefficient, C_2 (apparently the principal and controlling factor of the formula, for the uses made of it by the writers); and those values are believed to be based on local experimental observations of the evaporation depths, rather than on theory.

Mr. Horton states*:

"In this paper the specific result [the yearly evaporation depth from Lake Conchos] seems first to have been arrived at by guesswork. The authors, by repeatedly calling attention to this guess, as if it in reality was of some value as corroborating their results, have, unfortunately, and no doubt unintentionally, created the appearance that their investigation was for the purpose of corroborating the original guess. * * * it seems preferable to avoid if possible pre-influencing the mind by having any fixed figure set up in advance."

The writers regret that Mr. Horton should have gained that impression, for, as a matter of fact, they had no preconceived ideas as to the evaporation depth from Lake Conchos, and no choice between the value of 55 in. of Mr. Freeman and that of 83 in. of Mr. Stearns, until their own first value of 52.5 in. (Method *A*) was arrived at early in March, 1914, to be confirmed before the end of that month by the short-time evaporation tests at Lake Conchos entering into Methods *B* and *C*, and in August by the results of the longer-time local evaporation tests.

It is of interest here to explain how Mr. Freeman arrived at his value of 55 in. in 1911, as stated by him in a letter of November 19th, 1914:

"With reference to the evaporation from Lake Conchos: My judgment was not based on experiments for the Medina Reservoir, Texas, as I note you infer; but really was based on the elaborate investigations that I made near Prattville, Cal., in 1907, in connection with my studies of the Great Western Power project. At that time I maintained for upward of 6 months what was probably one of the very best meteorological observatories on the Pacific Coast. I had among other instruments a recording hygrometer which we checked up three times daily with a sling psychrometer; and had also an evaporating tank carefully constructed in the midst of a pond, on which (after first noting the small evaporation at night) I had for a week or two continuous observations made throughout the 24 hours.

"My recording hygrometer (which was carefully checked) showed that very soon after dark the relative humidity came down close to the dew point and staid there until sunrise, thus completely checking evaporation.

"I noted at La Boquilla (Lake Conchos), during my 2 weeks on the ground, a somewhat similar chilling of the air at night. I also

* *Proceedings*, Am. Soc. C. E., for May, 1916, p. 794.

had in mind the Salton Sea experiments, showing the progressive diminution of evaporation over a large pond area, as compared with a good tank on shore. Moreover, I have noted in Arizona while driving by irrigated and non-irrigated lands at night, the distinct difference in the feeling of the air on the leeward side as one passed a freshly irrigated tract; which helped confirm me in the belief (first started by observations on the windward and leeward sides of the pond at Prattville, Cal.) that after the air has had its thirst partly appeased, it drinks up water less rapidly". Messrs. Duryea and Haehl.

It appears to the writers that a value of evaporation depth arrived at by the judgment of an able engineer, of wide experience in that subject in similar regions, and after 2 weeks' observance of local conditions, is worthy of a better term than that of "guess" applied to it by Mr. Horton, even though Mr. Freeman's judgment was not aided by local tests of evaporation; and the writers do consider that the close agreement of his value with their own adds some corroborative weight to the latter.

As to "repeatedly calling attention to this guess"; Mr. Freeman's value is mentioned but twice in the paper, once on page 1735*, in connection with Mr. Stearns' value, and again on page 1738*, in connection with the writers'.

Mr. Hegly's Table 77† is of much interest as showing the comparatively uniform distribution of yearly evaporations among the 12 months, even for two such widely separated places (Lake Conchos, Mexico, and Arles, France) with presumably greatly differing climates. The same nearly uniform monthly distribution of evaporation is evident in Mr. Post's Table 62‡ (monthly distribution in Sweetwater Reservoir and in four pans, all near San Diego, Cal.); in the writers' Table 20§ (Piche evaporimeter records at eleven places and pan records at five places, all in Texas and New Mexico), and is best shown in a general comparative table—Table 93.

To show the comparatively small differences at the different localities, Table 93 may be summarized as given in Table 94.

The departures from the means at the ten places included in Table 93 average + 2.8 and — 2.5%, with extremes for the separate months of + (5.2 to 1.6)% and — (1.5 to 4.0) per cent. These values of departures seem small in themselves, but are of considerable magnitude in comparison with the average monthly percentage of 8.3.

The ten localities were chosen at random, merely because for them the monthly percentages were available quickly and easily. Though the monthly percentage values at the ten places are quite

* *Proceedings*, Am. Soc. C. E., for September, 1915.

† *Proceedings*, Am. Soc. C. E., for May, 1916, p. 790.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2703.

§ *Proceedings*, Am. Soc. C. E., for September, 1915, p. 1762.

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TABLE 93.—COMPARATIVE MONTHLY PERCENTAGE DISTRIBUTION OF YEARLY EVAPORATION DEPTHS, AT TEN WIDELY SEPARATED LOCALITIES.

Month.	MONTHLY PERCENTAGE DISTRIBUTION OF YEARLY EVAPORATION DEPTH AT:											
	(*a*) Lake Conchos, near Chihuahua, Mexico.	(*b*) Fifteen places in Southern Texas and New Mexico.		(*c*) Sweetwater Reservoir, near San Diego, Southern California.	(*d*) Kingsburg, near Fresno, California.	(*e*) Santa Clara Valley, California (near San Jose).	(*e*) Lake Tahoe, Northern California.	(*f*) Chestnut Hill, Boston, Mass.	(*f*) Lee Bridge, England.	(*g*) Emdrup, Denmark.	(*h*) Arles, near Marseilles, France.	Mean of Columns (1) to (11).
		Mean of Piche records at eleven places.	Mean of pan records at five places.									
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
	%	%	%	%	%	%	%	%	%	%	%	%
May	11.5	10.0	12.2	12.0	9.7	10.0	8.0	9.6	13.0	13.8	11.4	11.0
June	11.7	11.6	13.8	15.0	13.5	14.0	11.0	13.9	15.3	19.0	13.3	13.8
July	12.2	12.4	12.8	13.0	16.4	17.0	14.0	15.7	16.4	18.5	17.1	15.0
August	11.1 46.5	11.6 45.6	13.1 51.9	10.0 50.0	17.7 57.3	16.0 57.0	16.0 49.0	15.1 54.3	13.8 58.5	15.6 66.9	14.3 56.1	14.0 53.8
September	9.4	9.0	10.9	9.0	13.6	14.0	13.0	12.7	7.9	9.3	9.5	10.8
October	7.7	8.3	7.5	5.0	7.7	7.0	10.0	8.7	4.9	4.5	6.7	7.1
November	5.1	7.0	4.8	4.0	4.3	4.0	7.0	5.8	3.5	2.5	3.8	4.7
December	4.1	4.9	3.2	4.0	2.3	2.0	4.0	3.5	3.0	1.8	2.9	3.3
January	4.8	4.5	2.9	5.0	1.6	2.0	4.0	2.4	3.7	2.5	2.9	3 3
February	5.6	5.5	2.9	5.0	2.6	2.0	3.0	2.8	3.2	1.8	3.8	3.5
March	7.4	7.0	7.2	7.0	5.0	5.0	4.0	3.6	5.1	3.6	6.7	5.6
April	9.4 53.5	8.2 54.4	8.7 48.1	11.0 50.0	5.6 42.7	7.0 43.0	6.0 51.0	6.2 45.7	10.2 41.5	7.1 33.1	7.6 43.9	7.9 46.2
Year	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

(*a*) *Proceedings*, Am. Soc. C. E., for September, 1915 (Table 6), p. 1739; May, 1915 (Table 77), p. 790.
(*b*) *Proceedings*, Am. Soc. C. E., for September, 1915 (Table 20), p. 1762.
(*c*) *Proceedings*, Am. Soc. C. E., for December, 1915 (Tables 56 and 62), pp. 2699 and 2703.
(*d*) Computed from *Proceedings*, Am. Soc. C. E., for April, 1916 (Table 68), p. 568.
(*e*) *Engineering News*, Vol. 67, pp. 381–82 (February, 1912).
(*f*) Computed from *Proceedings*, Am. Soc. C. E., for April, 1916 (Table 69), p. 569.
(*g*) Fanning's "Water-Supply Engineering", 1906 (Table 24), p. 89.
(*h*) *Proceedings*, Am. Soc. C. E., for May, 1916 (Table 77), p. 790.

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TABLE 94.—MEAN OF MONTHLY PERCENTAGES OF YEARLY EVAPORATION DEPTH AT TEN LOCALITIES, WITH MAXIMUM DEPARTURES FROM MEAN.

Month.	Mean of monthly percentages.		Maximum departures from mean.			
May	11.0		+ 2.8%		and − 3.0%	
June	13.8		+ 5.2		and − 2.8	
July	15.0		+ 3.5		and − 2.8	
August	14.0	53.8%	+ 3.7	+ 13.1%	and − 4.0	− 8.2%
September	10.8		+ 3.2		and − 2.9	
October	7.1		+ 2.9		and − 2.6	
November	4.7		+ 2.3		and − 2.2	
December	3.3		+ 1.6		and − 1.5	
January	3.3		+ 1.7		and − 1.7	
February	3.5		+ 2.1		and − 1.7	
March	5.6		+ 1.8		and − 2.0	
April	7.9	46.2%	+ 3.1	+ 8.2%	and − 2.3	− 13.1%
Sums and Means	(8.3)	100.%	+ 2.8%	(+ 1.8%)	and − 2.5%	(− 1.8%)

uniform in a general way, and are most of them within rather narrow ranges, still in some instances they vary too much to permit the safe use of any general uniform values of monthly percentages.

Mr. Hegly's explanation of a greater proportion of the yearly evaporation occurring during the summer at Arles than at Lake Conchos* (because of the hotter and dryer summers at Arles) is interesting and probably true; since at Lake Conchos the rainy season, with its more humid conditions, occurs during the summer.

Mr. Hawgood's short discussion† is of much importance as calling attention to the Baldwin Latham experiments, showing the very great influence on the depths of pan evaporations of various elements (such as painted or unpainted pans, different colors with which the pans may be painted, etc., etc.) hardly ever recorded in the notes of evaporation tests. As bearing on such omissions, not only are all such data of painting, color, material of pan, etc., practically always omitted from the published data of pan evaporations, but it is exceptional when even the depth of the pan and of its water are mentioned, and not at all unusual to find omitted the size of the pan, whether land or floating, etc. Many such omissions occurred in the published Texas and New Mexico evaporation data used by the writers in this problem; and but few of them could be supplied, even by considerable time and effort in correspondence. Probably most engineers who have dealt with evaporation problems have been impressed with both the general scarcity and the incompleteness of the published data.

* See Table 93, Columns (1) and (11).

† *Proceedings*, Am. Soc. C. E., for February, 1916, pp. 247–49.

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As stated by Mr. Hawgood, there are many uncertainties in relative measurements of evaporations from pans and from reservoirs; and the utmost the writers ever have hoped for is the consideration of "their results and conclusions as a reasonable basis for reliable estimations", as stated by Mr. Hawgood.

As intimated already by the writers, they do not believe that any very useful results, of much practical value to engineers, can be attained by attempts to establish a "scientific formula" for evaporation depths, by which (from substitutions of the supposed evaporation effects of the various elements of a climate) reliable evaporation depths from reservoirs may be estimated synthetically.

Instead, they believe that useful advance in the estimation of evaporation losses is more likely to be in the direction of establishing gradually, in various scattered localities, an increasing number of fairly well founded values of evaporations from reservoirs themselves, from which (as a sort of primary network) evaporation values for contemplated intermediate reservoirs may be estimated by modification, by making comparative pan tests with the nearest primary reservoirs (supposedly under more or less similar climatic conditions), and working up the results of such pan comparisons by empirical and graphical methods, somewhat similar to those used by the writers in this paper.

TABLE 95.—MEASURED YEARLY RESERVOIR EVAPORATIONS NEAR SAN DIEGO, CAL.

Reservoir.	Years' Evaporation, in Inches, for:						Means, in inches.
	1910.	1911.	1912.	1913.	1914.	1915.	
* Sweetwater (5 years)	59.5	63.3	57.5	57.8	45.8	....	56.8
† Cuyamaca (4 years)	....	....	56.2	38.9	67.0	68.4	57.6
‡ Upper Otay (3 years)	....	....	....	61.1	67.5	58.2	62.3
Means	59.5	63.3	56.85	52.6	60.1	63.3	(58.9) 59.3

* From Table 56 (p. 2699), *Proceedings*, Am. Soc. C. E., for December, 1915.

† See explanation following Table.

‡ From Table 75 (p. 581), *Proceedings*, Am. Soc. C. E., for April, 1916.

As a beginning in the establishment of such a primary network of reasonably reliable values of evaporation from reservoirs themselves, it is believed that the data of measured reservoir evaporations in the vicinity of San Diego, Cal., contributed by Mr. Post* and Mr. Whitney† are of great and permanent value to engineers.

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2691–2703.

† *Proceedings*, Am. Soc. C. E., for April, 1916, pp. 575–82.

As mentioned by Mr. Hawgood,* measured evaporations from nearly all reservoirs are subject to the risk of more or less error because of the possibility of the loss of material quantities of the water by absorption and seepage; and it is realized that the San Diego data of Messrs. Post and Whitney are not without possibilities of such inaccuracies, and that, as presented, they include necessarily some assumptions and deductions. It is felt, however, that notwithstanding such possible inaccuracies, they will furnish by proper treatment a value for reservoir evaporation near San Diego, which may be regarded as fairly reliable and approximately correct. Messrs. Duryea and Haehl.

All the measured yearly evaporation depths from reservoirs near San Diego, Cal., are summarized in Table 95.

At the Cuyamaca Reservoir, reservoir evaporations were measured as follows:

Year †1912....	June	to September,	inclusive	(4 months)	= 28.12	in.
" 1913....	May	" "	"	(5 ")	= 23.73	"
" 1914....	March	" "	"	(7 ")	= 48.84	"
" 1915....	June	" "	"	(4 ")	= 34.22	"

From Tables 56 and 62,‡ the monthly distribution of the yearly evaporation depth was as follows at the near-by Sweetwater Reservoir:

March	5%	
April	7	
May	11	
June	12	
July	15	
August	13	
September	10	73%
October	9	
November	5	
December	4	
January	4	
February	5	
Year	100%	

and differed but little from the monthly distributions at four evaporation pans in the vicinity.

* *Proceedings*, Am. Soc. C. E., for February, 1916, p. 247.

† From Table 54 (p. 2697), *Proceedings*, Am. Soc. C. E., for December, 1915.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2699 and 2703.

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Assuming the same monthly distributions at the Cuyamaca Reservoir as at the Sweetwater, the corresponding probable yearly depths of evaporation at the Cuyamaca would be as follows:

	Measured.	Year (deduced).
1912—4 months, June to September, inclusive	= 28.12 in. ÷ 0.50 =	56.2 in.
1913—5 months, May to September, inclusive	= 23.73 in. ÷ 0.61 =	38.9 in.
1914—7 months, March to September, inclusive	= 48.84 in. ÷ 0.73 =	67.0 in.
1915—4 months, June to September, inclusive	= 34.22 in. ÷ 0.50 =	68.4 in.
Mean yearly	=	57.6 in.
"Weighted" mean yearly	=	58.4 in.

If the "mean" values of Table 95 are weighted for the numbers of years (Sweetwater, 5 years, Cuyamaca, 4 years, and Upper Otay, 3 years), or for the numbers of reservoirs (1 for 1910, 1 for 1911, 2 for 1912, 3 each for 1913 and 1914, and 2 for 1915), then such weighted mean value is 58.4 in. with a "weight" of 12 reservoir-years.

Table 95 includes values of yearly evaporation depth for 6 different years; and at three separate reservoirs, which (even though all near San Diego) differ from each other considerably in altitude and in location, and probably more or less in evaporation conditions. The altitudes of the three reservoirs are about as follows: Sweetwater 200 ft. above sea level, Upper Otay 500 ft., and Cuyamaca 4 600 ft.; their distances from the Pacific Coast are about as follows: Sweetwater 9 miles, Upper Otay 12 miles, and Cuyamaca 40 miles. Cuyamaca is about 32 miles from Sweetwater and about 31 miles from Upper Otay, and Sweetwater is about 6 miles from Upper Otay, and all the intervening lands are quite rough and mountainous.

Because of the three different reservoirs and the six different years, and because each of the 12 values of Table 95 may be the correct measure of a year's evaporation depth for its own place and year, the values of that table are not amenable to rejection or acceptance by the test of Peirce's criterion; though, if that test were applicable, at least two of the values would be rejected (the 38.9 in. for Cuyamaca in 1913, and the 45.8 in. for Sweetwater in 1914). However, even though the law of probable error is not strictly applicable to Table 95, if applied to its 12 values, the result is a probable error (?) of its mean (58.4 in.) of ± 1.7 in.

Hence, in so far as the 3 reservoirs, the 6 years, and the 12 values of Table 95 may be supposed to represent a fair range of evaporation conditions in the vicinity of San Diego, the value of 58.4 in. per year (not less than 56.7 nor more than 60.1 in.) evaporation from reservoirs, may be accepted tentatively as the most probable general value at present for that region. This is always subject to correction and amendment if additional values are secured for other years and for other reservoirs.

Similarly, the mean of the 5 yearly values for Sweetwater Reservoir has a probable error (?) of ± 2.0 in., the mean of the 4 values

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for Cuyamaca has a probable error (?) of $\pm$ 4.6 in., and the mean of the 3 values for Upper Otay has a probable error (?) of $\pm$ 1.9 in.

The various present tentative values of yearly evaporation from reservoirs, near San Diego, may be summarized as in Table 96.

TABLE 96.—PRESENT TENTATIVE VALUES OF YEARLY EVAPORATION FROM RESERVOIRS, NEAR SAN DIEGO, CAL.

Reservoir.	Altitude, in feet.	Period, in years.	Probable Evaporation Depth per Year.	
			Mean, in inches.	Probable error of mean, in inches.
Sweetwater........	200	5, 1910-14	56.8	$\pm$ 2.0
Cuyamaca........	4 600	4, 1912-15	57.6	$\pm$ 4.6
Upper Otay.......	500	3, 1913-15	62.3	$\pm$ 1.9
Near San Diego, Cal............	*1 700	6, 1910-15	58.4	*$\pm$ 1.7 (2.8 "weighted")

* If the "probable errors" of the three reservoirs are weighted in proportion to their numbers of years, the weighted average is $\pm$ 2.8 in., in comparison with the $\pm$ 1.7 in. of Table 96; and if the three altitudes are similarly weighted in proportion to their numbers of years, the resulting value (which may be called the "weighted average altitude") is about 1 700 ft.

The Principal Conclusion of the paper (the probable yearly evaporation depth from Lake Conchos) is shown in some detail in Tables 3 to 6; and the finally adopted value is 55 in., before the deduction of the rain falling directly on the lake surface. The various discussions of the Principal Conclusion will be considered next.

Mr. Mathewson* does not discuss the Principal Conclusion; but some use of his discussion already has been made,† and a slightly different use will be made of it here, as follows:

The altitude and the mean yearly temperature of the Botello power-house are, respectively, about 6 560 ft. and 62.4° Fahr.,‡ and those of Lake Conchos are about 4 300 ft. and 66.9° Fahr.§ From Diagram (*b*), Fig. 4 (from the larger-scale original drawing, extended by straight lines to altitude 6 560 ft.), the monthly evaporation in a 3-ft. floating-pan is 8.88 in., at altitude 6 560 ft. and mean temperature 62.4° Fahr.; and at 4 300 ft. and 66.9° it is 6.98 in., or 1.90 in. per month or 22.8 in. per year less, as measured in a 3-ft. floating-pan. From Subsidiary Conclusion (*c*), the corresponding less depth as measured in a reservoir should be (22.8×0.62) = 14.1 in. per year.

* *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2687–88.

† See pp. 1454–1456.

‡ Table 92 and Table 85.

§ Table 85.

Messrs. Duryea and Haehl.

From comparative local evaporation tests in a farm reservoir and in a small evaporation vessel, the La Botello engineers adopted 67.7 in.* as the value of yearly evaporation depth there from reservoirs; which, lessened by the estimated difference of 14.1 in., gives a corresponding yearly depth of evaporation from Lake Conchos of 53.6 in. This is 1.4 in., or 2.6%, less than the value of 55 in. adopted by the writers.

As admitted hereinbefore, this close check may be merely accidental; but, at the least, it does not weaken the validity of the writers' Principal Conclusion: that the yearly evaporation depth from Lake Conchos is about 55 in.

Mr. Chandler† refers to the writers' Principal Conclusion as follows:

"The conclusions drawn by the authors from this interesting and comprehensive investigation seem, in general, to be well founded and safely applicable in the region studied.

* * * * * * *

"* * * apparently the tables are not applicable with safety to places outside of the Great Plateau.

* * * * * * *

"* * * if good records of evaporation are available, extending through a period of several years, at some point not remote from the region where estimates [of evaporation] are needed, it seems that the methods illustrated so clearly and completely in this paper will provide excellent means for making the corrections needful for the differences in evaporation, caused by comparatively small differences in elevation and in mean temperature; but these methods are not suited for the transfer of figures from actual records to far distant regions, or to points where the mean temperature or elevation is, in great degree, different."

The writers cannot but agree, in general, with these remarks by Mr. Chandler.

Mr. Lee‡ discusses the writers' Principal Conclusion as follows:

"The authors have attempted, through assumptions and highly theoretical methods, carried out in great detail, to estimate annual evaporation from a lake surface more than 300 miles from the nearest point of actual observation. They have also attempted an exhaustive investigation and comprehensive analysis of the problem. They have based much of their framework, however, on a fundamental assumption§ which the writer believes to be in error. As a result thereof, the computed value of yearly gross evaporation from Lake Conchos, as set forth in Table 4, is far from the truth."

It is noticeable that the writers' methods, characterized by Mr. Lee as "highly theoretical", are instead characterized by Mr. Horton‖ "as almost wholly empirical".

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* See p. 1456.

† *Proceedings*, Am. Soc. C. E., for December, 1915, pp. 2688–91.

‡ *Proceedings*, Am. Soc. S. E., for December, 1915, p. 2704.

§ Subsidiary Conclusion $(c) = 0.62$.

‖ *Proceedings*, Am. Soc. C. E., for May, 1916, p. 793.

Mr. Lee is hardly correct in stating "the authors have attempted * * * to estimate annual evaporation from a lake surface more than 300 miles from the nearest point of actual observation". As a matter of fact, though his comment is partly true of Method *A*, no reliance was placed on the result by that method, and no use was made of it, until it apparently was confirmed by the results of Methods *B* and *C*, both based on observations of evaporation made at Lake Conchos itself. Messrs. Duryea and Haehl.

Apparently, Mr. Lee dissents from the writers' Principal Conclusion chiefly because of his dissent from Subsidiary Conclusion (*c*), he believing that the evaporation depth from a floating-pan is about the same as (and at least not materially greater than) that from the reservoir on which it is floating. This question has been discussed hereinbefore more or less fully,* with the writers' conclusion there that †"Subsidiary Conclusion (*c*) may be given at least tentative acceptance as expressive of the best data as yet available". Mr. Lee describes‡ some comparative evaporation tests made by him on Owens River and Lake, which seem to prove that the evaporations from the lake and from a pan floating on the river were the same, and hence to disprove (*c*); but the pan was about 20 miles from the lake, which may make the comparison somewhat doubtful, though he states that lake and pan have "practically the same climatic conditions".

In his reference to Method *C*, Table 46, and Piche evaporimeter computations, Mr. Lee is in error. Table 31 (from which Table 46 statedly is derived) is based only on evaporations observed from "3-ft. square floating-pans". However, it is seen from Table 20 that, in respect to the monthly percentage distributions of the yearly evaporation, apparently pan distributions and Piche distributions vary but little from each other.

Also, though Mr. Lee objects to the writers' expansions by Methods *B* and *C* from 2 to 7 months to a full year, and apparently has some ground for his objection, it is noticeable that all the yearly evaporations thus estimated by expansion (by B_a and B_b from 2 and 5 months,§ and by C_a and C_b from 4 and 7 months§) agree quite closely with one another, also with the yearly evaporation depth estimated by Method *A*,‖ which is independent of any method of expansion.

Referring to Mr. Lee's lack of confidence in Method *C*: the writers must acknowledge that the possible lack of sufficient precision, in the stream gauging rating curves and perhaps in some of the other measurements, may make the resulting values of the lake evaporation

* See pp. 1437–1446.

† See p. 1446.

‡ *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2711.

§ *Proceedings*, Am. Soc. C. E., for September, 1915, p. 1790, Tables 48 and 49.

‖ Tables 3 and 30 to 33, *Proceedings*, Am. Soc. C. E., for September, 1915.

Messrs. Duryea and Haehl. perhaps less accurate than they were thought to be, and that there may be some doubt (as suggested by Mr. Hawgood* and Mr. Comstock†) whether the average pan evaporation from such a large lake is represented closely by measurements in only one or two pans.

However, all measurements, of both pans and lake, were made with much care (probably with more care than generally is used for that class of work), the results of the two methods of working up the test observations for the two periods all agree with each other closely,‡ and it is felt that the probability of the yearly evaporation depths thus arrived at by Method *C* being seriously in error is not great. Also, in view of Professor Bigelow's deductions at Salton Sea (or at least of the writers' interpretation of them§), of Mr. Post's results secured at San Diego,§ and of those secured by the writers at Lake Conchos,§ and because a reasonable cause has been suggested therefor,‖ it is felt that, on the whole (even though the possibility of error is acknowledged), there is every probability that the evaporation from a reservoir is materially less than that from a 3-ft. pan floating thereon; and that the most probable value as yet (worthy of at least tentative acceptance) is about 62%, that used in Subsidiary Conclusion (*c*).

Much of the foregoing discussion of Mr. Lee's contribution will apply also to that of Mr. Comstock.¶

Referring to Mr. Comstock's statement that he **"has calculated the percentage distribution of evaporation at thirty stations in the United States, and has taken the mean for each month. The result shows 46% of the annual evaporation for the months, January to June, inclusive" (instead of the 50.4%†† used by the writers): the 50.4% is derived from observed mean monthly temperatures at Lake Conchos itself,‡‡ which monthly distributions (thus estimated) bear a close resemblance to the monthly distributions in Texas and New Mexico.§§ The 50.4% thus estimated seems more worthy of confidence than the 46% estimated "at thirty stations in the United States", especially as Table 93 shows that monthly percentage distributions of yearly evaporations, while not differing greatly from each other at different places, still do differ enough to make it quite advisable to compare only with places as near as practicable and having similar climatic characteristics.

* *Proceedings*, Am. Soc. C. E., for February, 1916, p. 247.

† *Proceedings*, Am. Soc. C. E., for March, 1916, pp. 401–2.

‡ Tables 48 to 50.

§ All discussed on pp. 1437–1446.

‖ See p. 1439.

¶ *Proceedings*, Am. Soc. C. E., for March, 1916, pp. 401–02.

** *Proceedings*, Am. Soc. C. E., for March, 1916, p. 401.

†† *Proceedings*, Am. Soc. C. E., for September, 1915, p. 1784.

‡‡ Table 31.

§§ Fig. 11.

Referring to the writers' Principal Conclusion (that the probable annual evaporation depth from Lake Conchos is about 55 in.), Mr. Grunsky says: Messrs. Duryea and Haehl.

*"On the assumption that the mean monthly temperatures [at Lake Conchos] are about as shown in Table 30, * * * the Kingsburg curve [Fig. 28] indicates a mean annual evaporation from the water surface of Lake Conchos of 60 in. This is subject to correction for higher elevation. (Lake Conchos is at Elevation 4 300 and Kingsburg is about at Elevation 300.) This correction is perhaps but little in the hot summer months, but may affect the results materially in the cold winter months. It is believed that this correction will not be as great as the curves presented in the paper would indicate, but, nevertheless, it may be an increase of from 20 to 30 per cent. It is the writer's opinion that further observations at Lake Conchos will show that the evaporation there will be between the 60 in. indicated by the Kingsburg curve and the 85 in. which the authors have estimated as the annual evaporation from a 3-ft. square pan floating on the water surface of the lake.

"The results at Kingsburg, though not recommended as fully dependable, have been tested by the fall of the water surface at Salton Sea, where the check was satisfactory for the year 1907-1908."

Mr. Grunsky's opinion—that the mean annual evaporation from the surface of Lake Conchos is between 60 and 85 in. (instead of being the 55 in. found by the writers)—apparently is based on an assumption that the climates of Kingsburg and Lake Conchos differ but little from each other except in mean temperatures and in altitudes. This, however, is not the fact. As pointed out by Mr. Jorgensen,

†"At Lake Conchos, fortunately, the rainy season coincides with the season of maximum temperature, and this condition undoubtedly tends to keep down evaporation loss; otherwise one would expect the yearly evaporation depths there to be higher than 55 in., due to the high average temperature and the very irregular shape of the lake."

At Kingsburg the rainy season (with its higher humidity) occurs in the winter, when the mean temperatures and the monthly evaporations are the least; at Lake Conchos, Mexico, it occurs in the summer. Thus Lake Conchos has higher relative humidities and lower relative mean temperatures and monthly evaporations throughout the summer, than Kingsburg. Hence it is believed that Mr. Grunsky is not justified in estimating a Lake Conchos evaporation value from his Kingsburg curve, with no other corrections except that for the difference in the altitudes; and that any Lake Conchos evaporation thus estimated necessarily must be greater than the true value.

Also opposed to Mr. Grunsky's opinion (that the probable mean annual evaporation depth from Lake Conchos is between 60 and 85

* *Proceedings*, Am. Soc. C. E., for April, 1916, p. 573.

† *Proceedings*, Am. Soc. C. E., for January, 1916, p. 164.

Messrs. Duryea and Haehl. in.) is the opinion of Mr. Freeman, who, after 2 weeks spent there in 1911 in study of the La Boquilla project, reported that in his opinion the annual evaporation from the lake would be about 55 in.;* and the value of 53.6 in. for Lake Conchos deduced by the writers† with the aid of Fig. 4 from a carefully estimated value of reservoir evaporation at the Botello power-house. The Botello power-house is about 600 miles south of Lake Conchos, but still within the limits of the Great Plateau, and presumably with climatic characteristics quite similar to those at Lake Conchos.

This close check on the writers' Principal Conclusion of 55 in. possibly is merely an accidental coincidence; but, unless such, it adds at least some corroborative weight to the validity of their Principal Conclusion, of their Subsidiary Conclusion (*c*) (that the evaporation depth from a reservoir is only about 62% of that from a 3-ft. pan floating thereon), and to the proper applicability of Fig. 4 to at least one other locality on the Great Plateau, at great distances from both Lake Conchos and Southern Texas and New Mexico.

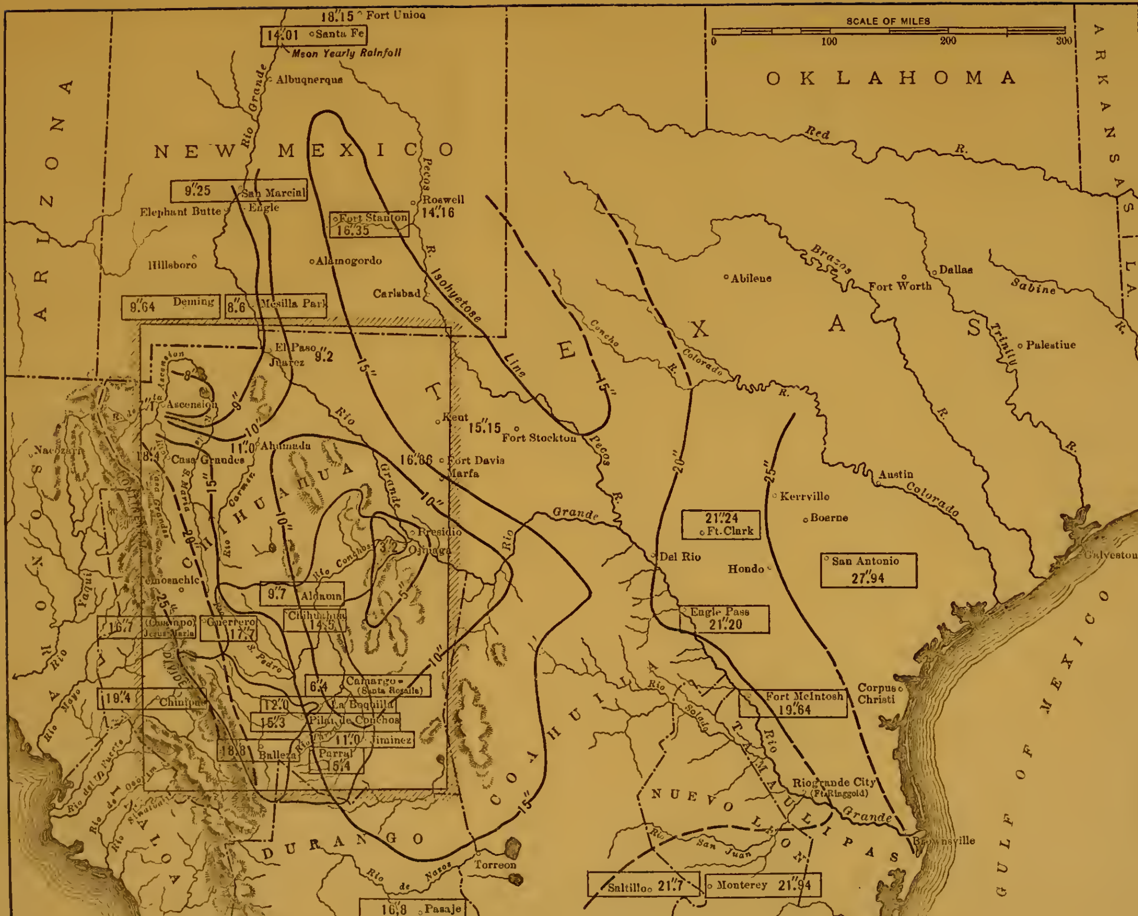
The paper and its discussions include annual evaporation depths from reservoirs (with corresponding altitudes and mean temperatures) not only at Lake Conchos and at the Botello power-house, but also at the Salton Sea (estimated by Mr. Grunsky and others) and at the Cuyamaca Reservoir (measured by Mr. Post). Merely from curiosity, Fig. 4 was applied to the Salton Sea and to the Cuyamaca Reservoir; and in both instances the resulting annual evaporations by the diagram from 3-ft. floating-pans gave (when multiplied by the 62% value of (*c*)) an estimated value of the annual evaporation depth from the lake or reservoir which was much smaller than the evaporation locally estimated or measured. This is not surprising, however, as both Salton Sea and Cuyamaca Reservoir are far removed from the Great Plateau and its conditions, and presumably with very dissimilar climatic characteristics.

In determining the probable power production of the La Boquilla project, a careful study was made by the writers of the rainfall and stream flow of the State of Chihuahua and parts of Northern Mexico; and the most important of the data acquired during that study are given here as contributions toward future hydrographic investigations of that region.

The rainfall data thus offered are given in the form of the isohyetose map, Plate XIII; and as Tables 79 to 82, 90, and 91, and parts of Tables 97 and 98. The stream flow data are given as Tables 83 and 84 and parts of Tables 97 and 98. In Tables 85, 86, and 92 are given data of mean, mean maximum, and mean minimum, temperatures; in Tables 93 and 94, data of the monthly percentage distributions of

* See pp. 1458–1459.

† See pp. 1465–1466.



ISOHYETOSE MAP

SHOWING

LINES OF

EQUAL YEARLY MEAN RAINFALLS

IN

PARTS OF NORTHERN MEXICO

The object of this Map is to show by Isohyetose lines the probable distribution of the mean yearly rainfall over parts of Northern Mexico; also the location and mean yearly rainfall of each of the rainfall stations used in the construction of the map (most of them shown in heavy oblong rectangles.)

This Map is based on mean yearly rainfalls shown in Tables 79 and 82.

Another Isohyetose Map, to a larger scale, was made to cover the Rio Conchos catchment area. The general location of this larger map is shown within the lines marked ////////////.

the yearly evaporation, at several places; in Tables 95 and 96, summarized data of the measured reservoir-evaporations near San Diego, Cal.; and in Table 99, data of maximum flood rates of the Rio Conchos at La Boquilla. Messrs. Duryea and Haehl.

Rainfall Data.—The isohyetose map, Plate XIII, was constructed from the mean yearly rainfalls of Tables 79 and 82 and some few additional data, and is believed to be fairly reliable in a broad sense for such a map, with a tendency to too low rather than to too high mean yearly rainfalls.

Stream Flow Data.—As explained already, the flows of the Rio Conchos were measured at its mouth for the 14 years, 1900-1913, inclusive. The measurements there were discontinued early in 1914. Its flow was measured also at Lake Conchos for the 6 years, 1910-1915, inclusive, and the measurements there are being continued.

The flows measured at the mouth of the Rio Conchos are given in Table 97 and those at Lake Conchos in Table 98.

TABLE 97.—MEASURED TOTAL STREAM FLOW AND DEDUCED AVERAGE YEARLY RAINFALL, OF THE ENTIRE DRAINAGE AREA OF THE RIO CONCHOS ABOVE ITS MOUTH, FOR EACH OF THE 14 YEARS, 1900-1913.

(This drainage area is very nearly 23 000 sq. miles.)

Year.	AVERAGE RAINFALL ON AREA:		MEASURED YEARLY STREAM FLOW OF RIO CONCHOS AT ITS MOUTH:		
	Year's rainfall as a percentage of the mean rainfall.	Year's rainfall, average depth, in inches.	As a uniform depth, in inches, on drainage area.	As a percentage of the yearly rainfall.	As cubic feet per second per square mile of drainage area.
(1)	(2)	(3)	(4)	(5)	(6)
1900	(123)*	17.6	0.86	4.9	0.0633
1901	80	11.4	0.32	2.8	0.0236
1902	97	13.9	1.20	8.6	0.0885
1903	93	13.3	0.54	4.1	0.0398
1904	110	15.7	1.84	11.7	0.1355
1905	152	21.7	2.02	9.3	0.1487
1906	126	18.0	2.31	12.8	0.1702
1907	96	13.7	1.08	7.9	0.0796
1908	84	12.0	0.79	6.6	0.0582
1909	85	12.2	1.10	9.0	0.0810
1910	50	7.2	0.47	6.5	0.0346
1911	122	17.4	1.48	8.5	0.1090
1912	(91)*	13.0	1.18	9.1	0.0870
1913	(113)*	16.2	0.73	4.5	0.0538
	(101.5)	....	....	....	(0.0838)
Averages	101.5	14.52†	1.14	7.86	0.0840

* The rainfalls of 1900, 1912, and 1913 are less reliable than those of the other years, because based almost wholly on American rainfall data.

† The deduced mean yearly area-rainfall for a long period (62 years) is 14.3 in.

Messrs. Duryea and Haehl.

TABLE 98.—MEASURED TOTAL STREAM FLOW AND DEDUCED AVERAGE YEARLY RAINFALL, OF THE ENTIRE DRAINAGE AREA OF THE RIO CONCHOS ABOVE LA BOQUILLA, FOR EACH OF THE 6 YEARS, 1910-1915.

(This drainage area is very nearly 7 000 sq. miles.)

Year.	AVERAGE RAINFALL ON AREA:		MEASURED YEARLY STREAM FLOW OF RIO CONCHOS AT LA BOQUILLA:		
	Year's rainfall as a percentage of the mean rainfall.	Year's rainfall, average depth, in inches.	As a uniform depth, in inches, on drainage area.	As a percentage of the yearly rainfall.	As cubic feet per second per square mile of drainage area.
1910...........	50	9.6	1.29	13.5	0.0955
1911...........	122	23.4	2.28	9.8	0.1680
1912...........	91	17.5	2.05	11.7	0.1515
1913...........	113	21.7	1.48	6.8	0.1088
1914...........	(128)*	(24.6)*	5.29	21.5	0.3890
1915...........	(131)*	(25.2)*	2.11	8.4	0.1552
Averages..	(105.8)	(20.3)	(2.42)	(12.0)	(0.1780)
	......	19.2†	2.17†	12.6†	0.160†

* Less accurate than other years, only two rainfall stations.

† Deduced means for long period, 62 years.

Columns (3) and (5) of Table 97 were plotted on co-ordinate paper, and upper and lower envelopes drawn of twelve of the fourteen points. The corresponding equations of the upper and lower envelopes and of the "median" (not far from the "mean") line are as follows:

$$\left.\begin{array}{l}\text{Year's stream flow}\\ \text{as a percentage}\\ \text{of the year's}\\ \text{rainfall}\end{array}\right\} = \left\{\begin{array}{l}\text{Upper envelope—}\\ \qquad [(\text{Inches of rainfall} \times 0.633) + 2.2]\%\\ \text{Median line—}\\ \qquad [(\text{Inches of rainfall} \times 0.633) - 1.3]\%\\ \text{Lower envelope—}\\ \qquad [(\text{Inches of rainfall} \times 0.633) - 4.8]\%\end{array}\right.$$

Year's Stream Flow at La Boquilla, as a Percentage of That at the Mouth of the Rio Conchos.—Stream flows were measured at both places for each of the 4 years 1910-13, with some variations in the accuracy and reliability of the Lake Conchos measurements in the different years. A comparison of the measured flow at La Boquilla each year, with the flow at the mouth of the river in the same year, gave the following relative flows:

1910—Total flow at La Boquilla = 86% of that at mouth.
1911— " " " " " = 47% " " " "
1912— " " " " " = 54% " " " "
1913— " " " " " = 62% " " " "

The most accurate of the years' measurements of stream flow at La Boquilla is believed to be that for 1912, with those for 1910 and 1911 less accurate and reliable than the others. Messrs. Duryea and Haehl.

The year of lowest total stream flow at both places was 1910, with 1913 next higher, 1912 still higher, and 1911 highest. Hence it appears probable (as would be expected) that in years of low total stream flow the total flow at Lake Conchos is a greater percentage of the total flow at the mouth of the river, than it is in years of high stream flow.

A careful comparative study was made of the cumulative monthly stream flows at the two places for periods of 12, 24, 36, and 48 months, both with the years in their natural chronological order and re-arranged in the order of their supposed accuracies. Considered in either way, it was found that at the end of 24 months the cumulative stream flow at La Boquilla was 57% of that at the mouth of the river, the same at the end of 48 months, and not materially different at the end of 36 months. As a final conclusion, the flow of the Rio Conchos at La Boquilla (from its about 7 000 sq. miles of drainage area) was adopted as a straight 55% of that at the mouth of the river (from its about 23 000 sq. miles of total drainage area).

Hence it is believed that the intensity of the total yearly stream flow from the upper 7 000 sq. miles of the Rio Conchos drainage area is about $\left(\frac{55}{7\,000} \div \frac{100}{23\,000}\right) = 1.8$ times as great as the average intensity from the total including drainage area (above the mouth of the river) of about 23 000 sq. miles.

Probable Maximum Flood Flows from Lake Conchos.—In 1911 Mr. Freeman made as careful an examination as practicable of former maximum floods of the Rio Conchos at La Boquilla, basing his study on a few gaugings of the river and on the flood marks of past years as pointed out by "oldest inhabitants". The results of his study are given in Table 99.

TABLE 99.—PROBABLE MAXIMUM FLOOD RATES OF THE RIO CONCHOS AT LA BOQUILLA, MEXICO, AS DEDUCED IN 1911 BY JOHN R. FREEMAN, M. AM. SOC. C. E.

Flood of year.	Probable maximum total flood flows (at crest of flood), in cubic feet per second.	Probable maximum flood flows per square mile of tributary drainage area, based on the most probable area of 7 100 sq. miles, in cubic feet per second per square mile.
1904	161 000	22.6
1868	230 000	32.6
1829	335 000	47.2
Usual *	134 000	18.9

* Probable extreme flood height of ordinary year.

Messrs. Duryea and Haehl.

Before Mr. Freeman's investigation, there had been adopted a spillway capacity of 2 000 cu. m. per sec. (70 600 cu. ft. per sec. total, or 10.0 cu. ft. per sec. per sq. mile). As a result of his investigation, a spillway capacity was adopted of 10 000 cu. m. per sec. (353 000 cu. ft. per sec. total, or 49.8 cu. ft. per sec. per sq. mile); and the spillway dam was constructed to carry that flow, with a depth of water of 3 m. (9.84 ft.) on its crest.

In closing this discussion, the writers (though acknowledging some inaccuracies and defects in the paper, pointed out in the discussions) still feel that they may claim for it that, in the words of Mr. Horton,

"* * * the work done in attempting a correlation of evaporation with temperature and altitude represents a start in a much needed investigation, and contains suggestions which may be useful in solving the vexed problem of the relation of evaporation to altitude".

Also, they feel that they may claim some permanent value for the paper because of the data it contributes to the rather meager knowledge of evaporation, rainfall, stream flow, and temperature in Northern Mexico—knowledge of much importance in connection with probable future hydraulic developments in that region.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

METHOD OF DESIGNING A RECTANGULAR REINFORCED CONCRETE FLAT SLAB, EACH SIDE OF WHICH RESTS ON EITHER RIGID OR YIELDING SUPPORTS

Discussion.*

By A. C. Janni, M. Am. Soc. C. E.†

A. C. Janni,‡ M. Am. Soc. C. E. (by letter).||—In Fig. 13 let A-B be a beam deflected as shown. It is known, from an *a posteriori* demonstration by Saint-Venant, that any of its cross-sections, for instance, c-d-e-f, after deflection, is transformed to the section, c'-d'-e'-f'. Mr. Janni.

This section, drawn in exaggerated scale, is obtained, as is well known, by keeping m'-n' as long as m-n, assuming a certain center, C', on the line, O-C', and drawing the arc, m'-n'. All the other fibers, like c'-d', and e'-f', are to be derived with the same center, C'; the straight lines, e'-c' and d'-f', will pass through the center, C'.

In Fig. 13, therefore, it is seen that each fiber above m'-n' undergoes a shortening which increases with its distance from m'-n'. The reverse—that is to say, the stretching of the fibers—happens for all fibers below m'-n'.

Poisson's coefficient, $\frac{1}{m}$, is simply the numerical translation of the physical phenomenon just described, and everybody understands that, in order to take it into account in an exact formula, it cannot be represented graphically very well, hence, tests have been made and have brought out various values for $\frac{1}{m}$, and these are not so far from $\frac{1}{4}$,

* Discussion of the paper by A. C. Janni, M. Am. Soc. C. E., continued from September, 1916, *Proceedings*.

† Author's closure.

‡ New York City.

|| Received by the Secretary, September 13th, 1916.

Mr. Janni. its theoretical value, as some seem to think. The tests mentioned, of course, were made by reliable scientists.

The general formula for the exact computation of stresses in beam deflection contains, in fact, the coefficient, $\frac{1}{m}$, as can be seen:

$$k = \text{Max.}\ \frac{M}{I}\left(\frac{m-1}{2\,m}\,h + \frac{m+1}{2\,m}\sqrt{h^2 + 4\,S^2}\right) \ldots\ldots(24)$$

where, M, I, m, and h have the same meaning as given in the paper, and S is the shear.

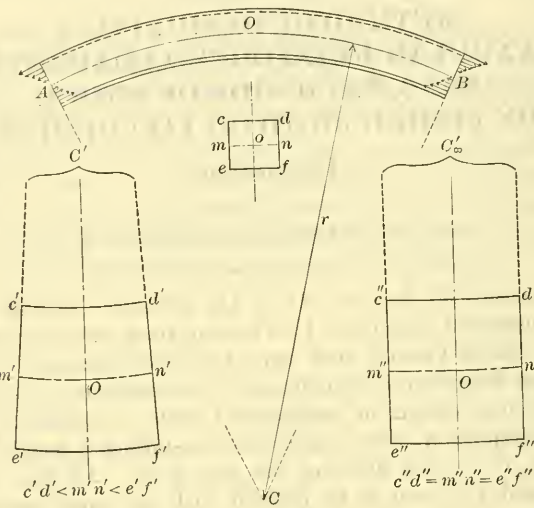


FIG. 13.

For every-day purposes, however, it is sufficient to verify the foregoing only at the top and bottom fibers and at the neutral axis, where it becomes, respectively:

$$k_1 = f_1 = \frac{M}{I}\,h, \text{ and } k_2 = f_2 = \frac{m+1}{m}\,S \ldots\ldots\ldots\ldots(25)$$

This shows that f_1, which we usually look for, is not a maximum, by any means, and that the indiscriminate use of this formula may lead to serious errors.

Fig. 13 shows, also, that, except for the neutral plane fibers, all the others of the cross-section are affected by Poisson's coefficient, and, therefore, the deflection of the beam is affected accordingly, although, for practical purposes, its influence may be ignored.

Now, if this same beam, *A-B*, is one of the ideal middle beams of a flat slab, its cross-section, *c-d-e-f*, on account of the continuity

of the system of beams, cannot be deformed as the section, c'-d'-e'-f', was. Mr. Janni.

Then, we will have, as in Fig. 13, m''-n'' = m'-n' = m-n, and c''-d'' = e''-f'' = m''-n''; that is, the center, C', is at infinity and becomes C'_∞, and the fibers, c''-d'', e''-f'', will be parallel to m''-n'' as before, having, furthermore, a less pronounced curvature, which is the curvature of the ideal beam of the other system, crossing the first beam at that point.

We have before us, therefore, the shapes of the same cross-section of a deflected beam, the first by the hypothesis that the fibers of the beam during deflection have freedom of deformation, the second by the hypothesis that those fibers are prevented from deforming.

The enlarged deformed cross-sections, in other words, represent the difference in the behavior of the cross-section of the same beam by the hypothesis of a single beam, and by the assumption that this beam is the middle one of a system of parallel beams connected with each other in such a way that the deformation of its cross-section is prevented.

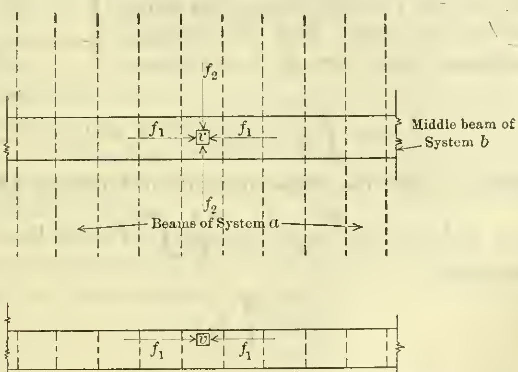


FIG. 14.

The absence of this phenomenon of deformation in this second case is essential to the behavior of the material in flat slabs, and, in order to take it into account in this investigation, it must be carried numerically in any formula the purpose of which is the finding of stresses in those ideal beams.

Accordingly, imagine that the ideal middle beam of System b is detached from all the beams of System a, Fig. 14, and is represented by v, an elementary cubical element of this beam.

Four forces will act on the vertical faces of this element. Two of these, f_1, are due to the deflection of the beam itself, and the other two, f_2, are due to the deflection of the ideal beam of System a, which, at that point, crosses the beam under consideration.

Mr. Janni.

Let e_1 and e_2 be the corresponding elastic deformations of the element, v, in these two directions; then,

$$e_1 = \frac{1}{E}\left(f_1 - \frac{1}{m} f_2\right) \qquad (26)$$

and,

$$e_2 = \frac{1}{E}\left(f_2 - \frac{1}{m} f_1\right) \qquad (27)$$

The deformation, e_2, must be zero, for the reason stated above. We have, therefore,

$$f_2 = \frac{1}{m} f_1 \qquad (28)$$

Hence,

$$e_1 = \frac{m^2 - 1}{m^2} \times \frac{f_1}{E} \qquad (29)$$

Now, if we consider two parallel contiguous sections of the beam, S_1 and S_2, as shown in Fig. 15, and a fiber, f, having a cross-section, dA, and a length, dx, the derivative of its work of deformation—assuming that the acting force, f_1, increases from zero to f_1—is given by

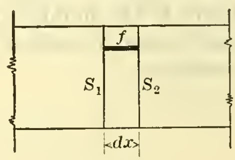


FIG. 15.

$$d\,L = \int \frac{1}{2} f_1 \times e_1 \times d\,A \times d\,x \qquad (30)$$

Substituting in this the value of e_1 from Equation (29), we have,

$$d\,L = \frac{1}{2} \times \frac{m^2 - 1}{m^2} \times \frac{d\,x}{E} \int f_1^2 \times d\,A \qquad (31)$$

but we know that,

$$f_1 = \frac{M}{I} h \qquad (32)$$

hence,

$$d\,L = \frac{m^2 - 1}{m^2} \times \frac{M^2 \times d\,x}{2\,E\,I^2} \int h^2 \times d\,A = \frac{m^2 - 1}{m^2} \times \frac{M^2 \times d\,x}{2\,E\,I} \qquad (33)$$

Therefore, the work of deformation, as given by Equation (2), is justified.

In establishing the values of V_A, M_{AC}, and M_O, it has been assumed, for the sake of simplicity, that the beam, A-B, was loaded with the uniform load, w. This, of course, gives, for M_{AC} and M_O values a little higher than the actual ones, but the complexity resulting from assuming the parabolic law of loading would not be justified by the results in a practical application.

In order to leave no doubt as to the correctness of Equations (21), (22), and (23), giving the values of V_A, M_{AC}, and M_O, the method used in deriving them is given, as follows: Considering the general

equation for the maximum moment in a single span, quasi-rigidly supported at its ends, and yielding vertically at one of its supports, and given by theory as Mr. Janni.

$$M_{max.} = M_A + \frac{V_A^2}{2\,w},$$

and applying it to the span, $A\ C$, Fig. 1, where, $M_A = 0$, we will have

$$M_{AC} = \frac{V_A^2}{2\,w}.$$

As

$$M_C = V_A\, l_1 - \frac{w\, l_1^2}{2},$$

the vertical reaction, V_A, at A, will be

$$V_A = \frac{1}{2}\, w\, l_1 + \frac{M_C}{l_1}.$$

As stated in the Synopsis of the paper, the writer's intention was to show the great divergency of results obtained by the two different hypotheses. The use of the first assumption, namely, unyielding supports, when the designer has to deal with several panels, as is generally the case, is erroneous.

This problem, no doubt, is one of the most difficult, and a strictly mathematical solution, taking into account the peculiarities of this material of construction, seems to be impossible. This difficulty, however, cannot justify the silence of the building codes on this subject. A reasonable approximation is always possible, and the practical example in the paper gives an idea.

In view of all these considerations, Mr. Godfrey will see that the writer, in order to find the equation of the elastic line, in this particular case, could not use the customary expression,

$$\frac{d^2\, y}{d\, x^2} = \frac{M}{E\, I},$$

which, as Mr. Godfrey knows, is only approximate, although for everyday work it is reasonably satisfactory, since, as has been stated, it would not have brought out the principal physical phenomenon happening in the deflection of a slab.

From Equations (10) and (11), the writer derives a smaller value for D than from the equations obtained according to Mr. Godfrey's suggestion; this difference between the two results is caused simply by the difference in the conditions of the two deflections of the same beam by the two hypotheses.

In order to be clear, it may be stated that, in imagining the slab to be divided as has been done, two peculiar conditions have been created in those beams: The first is that the beams of System a help those of System b in carrying the load, and *vice versa*; hence the law of parabolic distribution of loading. The second is that these beams are not

Mr. Janni. free to deform crosswise; hence, the essential introduction of Poisson's coefficient in the equations.

By taking into account, as far as possible, all the differences between plain, single-beam deflection and ideal, slab-beam deflection, we will get nearer the truth for all practical purposes.

Mr. Godfrey's remark, that the parabolic law of load distribution is enough, because it takes into account already the association of the ideal beam, is not quite correct.

In the case of the flat slab, as in other cases of reinforced concrete construction, the reason for the very small deflections usually observed —or the elastic deformations—must be found in the fact that the material (generally speaking) is being compressed or stretched in two directions, normal to each other, which condition is very favorable to the working capacity of the material, as it prevents important deformations.

It is a fact that Poisson's coefficient is purely theoretical, as far as its value, 4, is concerned, but the writer cannot agree with Mr. Godfrey regarding its unreliability for practical purposes, as some tests have given values which differ somewhat from 4, and this discrepancy is due, undoubtedly, to inevitable errors of readings, instruments, etc., besides the fact that isotropic bodies (and concrete may be regarded as such) cease to be isotropic when they are subjected to stresses in only one direction.*

If, as Mr. Godfrey states, some engineers are unwilling to use this coefficient, even in typical cases, this does not mean that it should be omitted from the theory. Those same engineers should know that they are using it, in any case, when they assume the working stress for steel in shear in relation to the working stress for bending, etc.

The value, 4, of Poisson's ratio is intended for isotropic bodies, it is true, but Mr. Godfrey's attention is called to the fact that, in this case, we have to deal with concrete and steel, and the steel (reduced to concrete according to the assumed value of $\frac{E_s}{E_c}$) is placed in the two directions along which it is consistently assumed that the forces are working. In other words, by reducing properly the steel in concrete, we obtain a solid wholly of concrete in the two directions which are of interest in this problem. This, of course, is an approximation, but, taking into consideration the great difficulties of the problem, the writer believes that it is permissible.

The tension in concrete, as Mr. Godfrey well states, undoubtedly plays its rôle in flat slab deformation; and this is also a reason that Poisson's ratio cannot be ignored in this problem.

The use of Equations (12) and (17), and those for the square slab, can be made by practical designers without caring very much how

* Grashof, "Theorie der Elasticität und Festigkeit," Berlin, 1878.

they have been worked out, as is generally the case with formulas, as far as their mathematical derivation is concerned. Mr. Janni.

The writer will not discuss the question of priority in the method of treating a slab made up of several beams lying in two directions, as mentioned by Mr. Godfrey. In adopting this treatment, the writer never claimed originality.

Starting with the foregoing assumption, in the case of a flat slab design, the fact that, in a square slab, each middle strip at its middle square unit carries one-half the uniform load is self-evident, and the result given by Equation (12), when $l = l_1$, namely, $\alpha = \frac{1}{2}$, is a check of that equation, rather than a result.

To assume that the end moment, M_P, is two-thirds of the fixed-end condition, as has been done by the writer, is similar to—and with nearly the same degree of approximation—that which is made for fixed-end beams, in order to take care of the one-panel loading condition.

In order to demonstrate this statement, attention is called to the formulas, for instance, for the square slab case. There the numerical coefficients should be $\frac{1}{21.33}$ and $\frac{1}{26.94}$ (for a square slab, however, the writer has thought it expedient to state these values in round figures, namely, $\frac{1}{21}$ and $\frac{1}{27}$, in order to memorize them more easily), and those actual values, of course, must be taken for the following demonstration.

According to the accepted rule, the moments for a beam with assumed fixed ends are computed on the basis of the coefficients, $\frac{1}{10}$ and $\frac{1}{12}$ (respectively in the middle of the span and on the supports). These two coefficients give the following results:

$$\frac{1}{10} + \frac{1}{12} = 0.183 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (a)$$

$$\frac{1}{12} : \frac{1}{10} = 0.833 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (b)$$

and the coefficients resulting from the writer's assumption, remembering that these coefficients enter twice into the calculation of the moments for the same panel, will give:

$$2\left(\frac{1}{21.33} + \frac{1}{26.94}\right) = 0.168 \ldots\ldots\ldots\ldots\ldots\ldots (a')$$

$$\frac{1 \times 2}{26.94} : \frac{1 \times 2}{21.33} = 0.791 \ldots\ldots\ldots\ldots\ldots\ldots (b')$$

Mr. Janni. From a comparison of the foregoing equations, (a) with (a') and (b) with (b'), it will be seen that, even though the writer's assumption was "very rough", it would not be any rougher than that usually made for fixed-end beams. Mr. Godfrey's remark, therefore, may be regarded as a little precipitate.

It is true that a slab supported by girders on all edges does not find many users, but this paper is simply the result of the writer's designing of reinforced concrete floors, built years ago, according to these lines, by the expressed wish of the owner, and it was thought that the results might be useful in giving some hint, as stated at the end of the paper, as to a correct solution for flat slab floor design.

Undoubtedly, as Mr. Godfrey remarks, we are badly in need of serious tests in this line, but the writer is afraid that this will never be accomplished, as business has taken such a firm hold on the whole question.

Mr. Goodrich's contribution shows clearly that he understands fully the spirit of the paper. The writer has had no intention of adding any formulas to the more or less empirical ones already in existence, many of them misleading; but his aim has been to show the great influence of the elastic displacements of the supports on the values of the bending moments.

It has not been without a great deal of hesitation that the writer has undertaken to reply to Mr. Jonson. The only reason which prompted him to devote some time and space to this purpose has been the fact that his silence concerning Mr. Jonson's remarks might be interpreted as an acceptance of his statements.

Leaving to Mr. Jonson the responsibility for his statement that "the moment of inertia is not only a constant, but also a function", the writer must say that, when Mr. Jonson brings up the well-known question of the variability of the inertial moment of the reinforced concrete section, he shows quite clearly that he ignores the fact that this moment of inertia, as we find it, and as it was agreed on years ago, must not be intended for each and every stage of the deflection of the beam.

The position of the neutral axis in the cross-section of a reinforced concrete beam, and, consequently, its moment of inertia with respect to it, are purely conventional, as long as the stresses in the concrete and steel are below or above the stresses calculated, but, as soon as the stresses actually in the beam approach those calculated at that section, the actual position of the neutral axis is very close to, if not coinciding with, that assumed. However, if there is any discrepancy, the usual assumptions, in determining the position of the neutral axis, are on the safe side, and this must be so because the tension in concrete is disregarded.

The most important matter in designing a building of reinforced concrete or any other material is not strictly the exact correspondence between calculated and actual stresses, but, indeed, the safety of the building itself. Mr. Janni.

Designers know very well that the methods used in designing any kind of a building cannot be of such precision that they can be applied, for instance, to the construction of a Bauschinger's Spiegelapparat measuring $\frac{1}{5\,000}$ mm. of deformation.

Neither is it practical to design and construct buildings for ordinary purposes in the same way as beams and floor panels would be designed and built in a laboratory for scientific research.

Mr. Jonson's attention is called to the work done by the French Commission,* which was formed 16 years ago, and, after 6 years of very exhaustive study, published the results. Incidentally, in the writer's opinion, this work so far has been unsurpassed, either in America or Europe.

Mr. Jonson will find there that the question of the variability of E_c has been thoroughly investigated. He will also find that, in addition to all the causes bearing on this variability, mentioned in that work and repeated now by him, the Committee investigated the variation of this modulus due to the method of concreting (vertical or horizontal, post or beam); or due to the personal equation of laborers, etc.; and, finally, he will find that, after taking into account all possible causes, the value of $\frac{E_s}{E_c}$ was not decided on as a real constant quantity, but it was agreed to assume 8 and 15 as minimum and maximum limits, respectively; and this range of values for $\frac{E_s}{E_c}$ has been generally recognized as right, even after later tests and investigations.

The designer may make the choice—not capricious, but judicious—of the proper value of $\frac{E_s}{E_c}$, according to the circumstances. The misjudgment of the designer or of some building law, in the choice of this value, Mr. Jonson will agree, cannot be imputed to theory.

The question of shrinkage in concrete, as affecting the working stresses in a beam, which, from Mr. Jonson's discussion appears to be a discovery brought up by him for the first time, is also old; in fact, on page 371 of the aforesaid work of the French Commission, the first two questions which the Commission proposed to investigate, were as follows:

First.—*"Quelle est l'importance du phénomène du retrait?"*

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* Commission du Ciment Armé: Expériences, Rapports, et Propositions, Instructions Ministérielles Relatives à l'Emploi du Béton Armé, Paris, 1907.

Mr. Janni.

Second.—"*Doit-on en tenir compte dans les calculs de résistance?*" and, on the same page, the following answer is found:

"*Tout en affirmant le fait incontestable qu'est le retrait, la Commission a proposé d'autoriser les Ingénieurs à n'en pas tenir compte, lorsq'lys pourront justifier qu'il ne saurait en résulter d'inconvénients et il paraît en être généralement ainsi pour les supports et les planchers intérieurs des bâtiments dont les dimensions horizontales ne sont pas grandes.*"

The date of this report, and these quotations, will dispose of any possible doubt as to whether Mr. Jonson, having looked into "the entire theory on reinforced concrete" and having found it "rather crude", has brought out a new and important question.

Mr. Jonson, the writer is sure, must realize that the guesswork advocated by him in predicating the position, the direction, the number, and the size of cracks in a restrained reinforced concrete beam, does not and cannot interest an engineer during a serious technical discussion.

As he is attempting also to introduce a new method of designing, in order to take into account the shrinkage, as he says, it will not be amiss to show that this method is wrong.

To start with, Mr. Jonson says "All calculation of reinforced concrete made on the assumptions that the ratio, n or E divided by E_c, is a constant are unreliable", and rather inconsistently he proposes the use of formulas in which this very ratio appears, with the addition of a certain quantity, m, the introduction of which will be discussed later, and which would be an additional uncertain factor in designing.

Apart from many other considerations, however, it can be stated that, from what Mr. Jonson says and proposes to do, it is clear that he ignores that theory has a formula, as follows:

$$f = \pm \frac{N}{A} + \frac{M}{I} h$$

in which f is the maximum allowable stress; N, the compressive or tensile stress along the beam; A, the sectional area; M, the external moment; h, the distance between the farthest fiber and the neutral axis; and I, the inertial moment of the section.

Applying this formula to a reinforced concrete beam, when it is necessary at all, the stress in concrete and that in steel can be computed, remembering that, for practical purposes and for the sake of brevity, the second term of the second member, for reinforced concrete sections, is replaced by a simpler one.

Assume a 20-ft. reinforced concrete beam, with a section of 24 by 14 in., with 3.36 sq. in. of steel reinforcement; and assume that its length is kept constant, so that it is under the full tension caused by the unyielding of its ends during its setting.

As the coefficient of the shrinkage is known to be $\frac{1}{2\,000}$, this beam, after setting, is actually under a tensile strain of Mr. Janni.

$$\frac{20}{2\,000} = 0.01 \text{ ft.}, \quad 0.01 = \frac{N \times 20}{2.33 \times 144\,000}$$

$$\frac{N}{2.33} = 71.856 \text{ tons per sq. ft., or } 998 \text{ lb. per sq. in.}$$

so that each square inch of its concrete cross-section would be under the enormous tension of 998 lb.

Concerning the steel now, it is observed that the rise in temperature which takes place during the setting of the concrete, will increase the length of the reinforcement. This increase, which is the cause of tension in the steel during the first few weeks of hardening of the concrete, diminishes gradually with the further shrinking of the concrete, and, finally, becomes compression, but its value is negligible for all practical purposes.

As it was assumed, however, that the ends of the beam are absolutely unyielding horizontally, it must be assumed (as a matter of consistency) that the increased length in the reinforcement is kept constant.

Assuming, say, 25° Fahr. as the rise in temperature during setting, and assuming 0.0000067 as the coefficient of expansion for the steel, the tensile stress in the reinforcement will be 5 000 lb. per sq. in.

Now, if the bending moment acting on this beam were 1 195 444 in-lb., we would have 998 lb. per sq. in. compression in concrete, and 19 343 lb. per sq. in. tension in steel.

Adding algebraically these stresses to those found in the case of plain tension, we will have 0 lb. per sq. in. compression in concrete, and 24 343 lb. per sq. in. tension in steel.

Furthermore, with a moment M = 679 800 in-lb., we will have the total stresses in the concrete and steel as follows: minimum tension in concrete 431 lb. per sq. in., and tension in steel 16 000 lb. per sq. in.

These results, which are strictly correct, according to the assumption made (horizontally unyielding beam ends), need no further comment.

Everybody, even those not thoroughly familiar with concrete construction, knows that, in common cases, the unyielding of the beam ends is not possible, due to the elastic deformation of the whole construction, by which, providentially, the entire system takes up a condition of reciprocal adjustment among its various elements.

The absence of any perceptible crack in the great majority of reinforced concrete beams clearly supports this assertion; therefore, it

Mr. Janni.

must be assumed that, if there is any initial tension, it must be quite negligible in ordinary cases.

If, however, peculiar conditions of the building make it advisable to take into consideration the tension due to shrinkage, then the theory has already everything that is needed by the designer for this purpose, as has been shown.

In order to prove further that Mr. Jonson's theory is not only unnecessary, but is altogether wrong, attention is called to the following facts:

For the action of the axial tension (or compression) and that of a moment on a solid, may be substituted the action of an eccentric tension (or compression), so that, admitting the necessity seen by Mr. Jonson of taking into account in all cases the effects of shrinkage, the beam is to be regarded as a post (with eccentric negative compression).

Everybody knows that the position of the neutral axis, that is, the value of k, in this case, is given by an equation of the third degree, or, more speedily, by a certain graphical construction, but Mr. Jonson obtains for k an equation of the second degree and one of the first degree (his Equations (2) and (7)), *ad libitum*.

It can easily be seen that the diagram, Fig. 3, is drawn incorrectly, and therefore that the values of k are also incorrect.

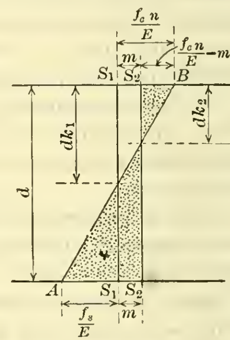

FIG. 16.

That diagram being incorrect (as will be demonstrated), Mr. Jonson's Equation (1) is incorrect, and so are all the succeeding equations which are derived either from his Equation (1) or from Fig. 3.

Let S_1-S_1 (Fig. 16) be the section of the beam under consideration; this section is under the action of a bending moment, the diagram of which may be represented by a straight line, A-B, where $S_1\text{-}B = \frac{f_c\, n}{E}$ is the maximum compressive stress, and $A\text{-}S_1 = \frac{f_s}{E}$ is the maximum tensile stress (or their proportional variations of length), and the value of k_1 can be found by the usual methods. (Analytically, the value of k_1 is given by an equation of the second degree.) The axial tensile force, acting on the section, S_1-S_1, will simply bring that section to a parallel position, S_2-S_2.

The diagram, therefore, of these two combined actions, will be represented by A-S_2-S_2-B-A, and the value of k_2, which corresponds to k in Fig. 3, is given, as stated previously, by a third degree equation only. A comparison of Fig. 16 with Fig. 3 will quickly show the mistake.

Mr. Janni.

Having demonstrated that the theory advanced by Mr. Jonson is "fundamentally wrong", and that the real theory is quite able to take care of shrinkage when that is necessary; and after having called attention to the fact that this problem is not new, as it was studied exhaustively 16 years ago, the writer thinks it expedient to disregard all Mr. Jonson's other remarks in this line, for the sake of brevity, and also because the statements and results, being on a false premise, must be wrong, and to reply to his discussion having direct bearing on the paper.

The writer agrees with Mr. Jonson that the moments of inertia cannot be the same in both directions, because the steel is not at the same altitude in the two systems; but if Mr. Jonson thinks that the percentage of steel is very small, and its size also, he will see that this is an approximation which may be allowed. In computing the moment of inertia of a reinforced concrete section, with a small quantity of steel, the steel may be disregarded entirely.

If, however, a more exact result is desired, Equation (12) may be corrected by a factor, $I = \frac{I_1}{I_2}$ where I_1 is the moment of inertia in one direction, and I_2 that in the other.

The writer certainly cannot agree with Mr. Jonson's statement: "economy demands that less reinforcement be used longitudinally than transversely". In fact, the moments at the center of each middle beam in a panel and those on the supports are tied together by the relations:

$$\frac{M_O}{M'_O} = \frac{l^2\,(7 + 43\,\alpha)}{l_1^2\,(50 - 43\,\alpha)}$$

$$\frac{M_P}{M'_C} = \frac{l^2\,(1 + 4\,\alpha)}{l_1^2\,(5 - 4\,\alpha)}$$

As stated in the paper, the value of α may vary between $\frac{1}{2}$ and 1, and inspection of the expressions mentioned shows that the maximum moments are on the shorter span; therefore, a larger quantity of steel must be used in that direction. Thus "economy demands" nothing; it is only a matter of results obtained by theory.

Mr. Jonson says:

> "The author's method implies the assumption that all moments are at a maximum when the entire floor is covered by the live load. This assumption is erroneous."

Then he gives the well-known "recipe" for obtaining the maximum moments in continuous beams, which he thinks the writer should have followed in order to be correct.

Mr. Janni.

Evidently, Mr. Jonson ignores the fact that the usual "recipe" does not hold good when the supports are elastic, that is, when they are displaced vertically under the loading. In fact, let Fig. 17 represent the middle beam under consideration in the paper, and suppose that C and D are unyielding; then, assuming that only the span, C-D, is loaded, and applying the theorem of three moments* to the supports, A, C, and D, and remembering that the moment at A is zero, and that the moments at C and D, by symmetry, are equal, we will obtain, with the same unit load as in the application treated before:

188 lb. (live load) = 300 lb. (total load) — 112 lb. (dead load),

$$M_C = 5\ 414 \text{ ft-lb.},$$

and, therefore, the moment, M_O, at the center of the span, C-D, will be given by:

$$M_O = \frac{1}{8} \times 188 \times (24)^2 - 5\ 414 = 8\ 122 \text{ ft-lb.}$$

If these results are compared with those obtained by the writer, when he took into consideration the yielding of the supports, C and D, as must be done, the value of Mr. Jonson's remark will undoubtedly be realized.

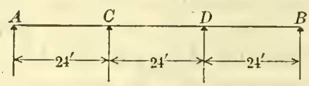

FIG. 17.

Incidentally, it may be noted that his statement concerning the most critical condition of partial loading is the very thing brought out by applying the theorem of three moments to a continuous beam, although Mr. Jonson states, a few lines before this remark, that "the theorem of three moments cannot be applied to reinforced concrete, nor any other method which deals in deflection components." In this, assuredly, there is also lack of consistency.

It is difficult to understand why, as Mr. Jonson states (the slab being regarded as having fixed edges, and its elastic curve, consequently, being a reversed one), the law of variation of loading "is more closely approximated by a straight line from end to middle than by a parabola"; indeed, it is the writer's opinion that this remark is altogether whimsical. In order to support this statement, however, Mr. Jonson makes the following remark: "The latter [the parabolic law] would be the proper approximation for a non-continuous slab merely supported along its edges".

As a matter of fact, if the parabolic law is the proper approximation for a non-continuous slab, it must be also for a continuous slab. In fact, let A-B-C (Fig. 18) be the parabola of bending moments for the beam, A-C, with the assumption that this beam is supported freely at its ends, and that the parabolic law of loading is adopted.

* The propriety of applying this theorem will be discussed later.

Mr. Janni.

If it is supposed now that its ends are fixed, the diagram of bending moments will be obtained, as shown by A'-B'-C'-E-D. The line, D-E, is to be determined by proper methods, and the parabola, A'-B'-C', is determined by the assumption that the beam, A'-C', is freely supported; therefore, this parabola must be the same as A-B-C.

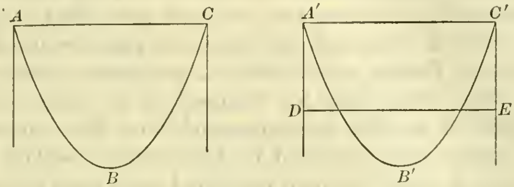

FIG. 18.

This question being settled, on the basis of theory, the writer thinks it expedient, in order to justify his assumption of the parabolic law, instead of the linear law, to show the behavior of the deformed axis of the same beam, subject to both a parabolic-law and a linear-law loading.

Fig. 19, obtained by Mohr's method, gives all the information necessary. Both diagrams represent the same beam, loaded first with a parabolic-law loading and then with the same total load, but distributed, as Mr. Jonson says it should be.

The parabola, C-O-D, represents the parabolic law of distribution of the loading, and E-O-F, the other assumption of distribution.

By using the same scale in the graphical constructions of the moment diagrams for both hypotheses, by taking the same polar distances in both cases and in each instance, we obtain the same distorted scale for the two diagrams representing the deformed axis of the beam, and, therefore, a comparison between them is made at a glance.

If reliable tests were made, it would be possible to state something definite concerning the degree of approximation of the two assumptions of loading; since, however, such tests are lacking, it may be said that the writer's assumption, already used by others, on the hypothesis of loading, is, at least, as good as that suggested by Mr. Jonson, without substantiating it in any way.

Incidentally, it will be remarked that, in assuming the parabolic law, the writer followed the very method just shown and found no reason to change what already had been done.

Mr. Jonson, it seems to the writer, is rather concerned that the paper, in some points, does not convey his (Mr. Jonson's) ideas, but the writer's ideas, and, accordingly, he attempts to correct what he thinks is erroneous.

Mr. Janni.

Mr. Jonson says:

"The statement on page 1690* that 'these beams, *a* and *b*, are carrying the same uniform load' is erroneous. The author probably intended to say 'because the beams, *a* and *b*, deflect the same, although their lengths are different, they cannot carry the same load.'"

The writer, however, stated correctly what he meant, for, in this case, he referred to uniform load, and not total load. Attentive reading of the second paragraph on the same page would show that the writer refers to Beams *a* as a system, comparing them among themselves; the same being done for Beams *b* of the other system.

The writer is unable to understand how Mr. Jonson found out that, in a square slab, designed by the writer's method, the quantity of steel required would be about one-third more than in a slab designed for a one-way reinforcement, for figures, which are not a matter of personal opinion, give altogether opposite results. In fact, the formulas given in the paper for the square slab are:

$$M = \frac{1}{21} w l^2 \text{ at center,}$$

$$M' = \frac{1}{27} w l^2 \text{ on supports.}$$

Taking the quantity of steel as a certain ratio of the moments, it will be found that the total steel in the two directions at the center of the middle beam will be proportional to $\frac{1}{10.5}$. On the supports, likewise, the total quantity of steel in both directions will be proportional to $\frac{1}{13.5}$.

According to building ordinances, the quantity of steel for one-way reinforcements must be proportional, respectively, to $\frac{1}{10}$ and $\frac{1}{12}$; therefore, the economy is quite evident.

There is another consideration, however; the quantity of steel required for a two-way reinforcement is referred only to the middle 1-ft. beam in each direction; but it would be progressively excessive in going toward the supports. It might be diminished by a parabolic law or a linear law without any difficulty, taking into consideration, of course, the practical side of the question.

The writer cannot agree with Mr. Jonson who thinks that the solution of a technical question must depend on the building law; the writer's opinion is just the reverse. Building laws, as a rule, are formulated on theoretical truths, and, even then, are not intended to be textbooks, by any means; and that thoroughly theoretical truths should be barred from the solution of a technical question, just because

* *Proceedings*, Am. Soc. C. E., for February, 1916.

Mr. Janni.

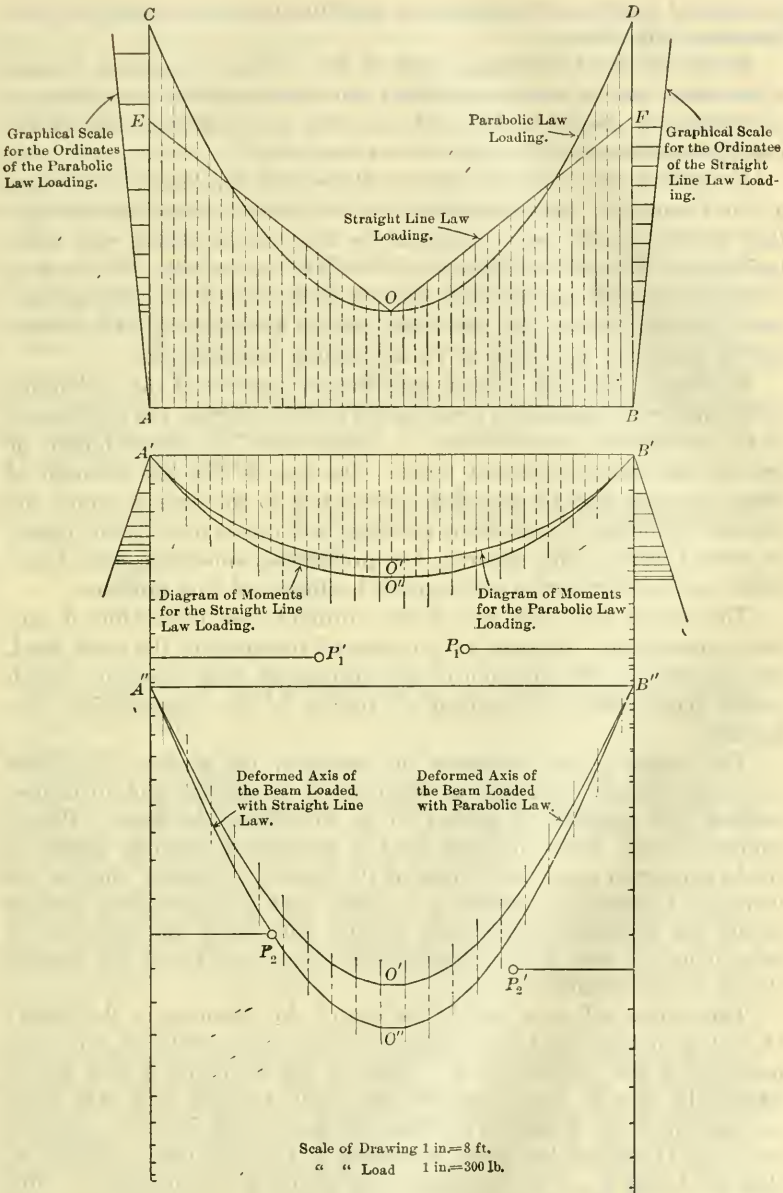

FIG. 19.

Mr. Janni. they might conflict with some stale building ordinance limitations, is somewhat ridiculous.

By far the most interesting part of Mr. Jonson's discussion is that which deals with a certain graphical construction which, according to his judgment, should be followed, in order to avoid "the illegitimate use of the theorem of three or of four moments."

In order to be clear, the writer will devote a few words to the use of the theorem of three moments, and will demonstrate, incidentally, that its use in the case considered by him in the paper, was quite legitimate. He will then deal with what Mr. Jonson calls "the theorem of four moments" and its quite correct application to reinforced concrete girders; finally, the graphical method proposed by Mr. Jonson will be taken up, with some of its astounding consequences.

Evidently, when Mr. Jonson says that, on account of the variability of the moment of inertia in a reinforced concrete girder, the application of the theorem of three moments is "illegitimate", he either forgets or ignores two fairly important facts: The first is that the theorem of three moments may be extended legitimately to the case in which the moment of inertia of a girder is variable; and this is done by the theory of virtual work. This theorem has progressed somewhat since Clapeyron, in 1857, first gave his simplified solution of this problem.

The second fact—and this is the ordinary case in reinforced concrete construction—is that, in the case of supports on the same level, the last term of the equation of the theorem of three moments, which would bring forth the moment of inertia of the cross-section, disappears.

The values of the moments on supports, for girders of various spans, are already calculated in engineering handbooks, and, of course, without any moment of inertia to be substituted in them. Hence, admitting only for a moment that a reinforced concrete girder is freely supported at several points of its length, no matter whether the moment of inertia is constant or variable, and no matter also whether or not its supporting points are on the same level, the equation of three moments may be used legitimately; this is as far as the general theory of this theorem applies.

The writer will now justify the use of this theorem in the paper: It will be noticed that the beam, *A-C-D-B*, rests freely on four supports, since the sections of this beam on the supports, *A* and *B*, are admittedly free to have whatever very small rotation may take place on account of the deflection of their own spans, and since the supports at *C* and *D* are not less loose, according to the temporary assumption, than at *A* and *B*. One should not take seriously the question of "torsional resistance" of the supporting girders at *C* and *D*, especially when, as it is assumed, the beam, *A-C-D-B*, is unloaded.

Mr. Janni.

Furthermore, the theorem of three moments has been used in order to find M''_C, that is, the moment at C when the assumed vertical displacement takes place, and this quite independently of any hypothesis of loading for the beam itself. In other words, having the supports, A, C, D, and B, on the same level, and the beam unloaded, if, for some reason, the supports, C and D, give way vertically, a certain moment will appear at C and D; this is the moment found by the writer by a quite legitimate use of the theorem of three moments.

Mr. Jonson directs attention to what he calls "the theorem of four moments", and gives information concerning a paper presented by him before this Society dealing with the subject. The writer has examined the paper referred to and finds that it deals with the analytical solution of the problem of finding the moments in a girder stiffly connected to its supports. This problem was treated by W. Ritter* in 1900; Mr. Jonson's paper appeared in 1905. It can be added, also, that some diagrams in this latter paper are incorrect. The reader may draw his own conclusions.

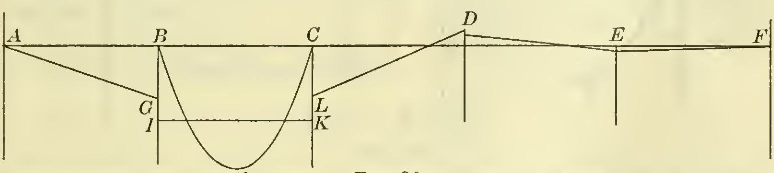

FIG. 20.

A few words will now be devoted to the solution of the problem involved in the case of a girder stiffly connected at various points of its length.

There are two different and mathematically correct solutions of this problem. One is a graphical solution by the method of the ellipse of elasticity, and the other is analytical, following Ritter's theory on this subject, as published in the book quoted.

For practical purposes, the graphical method, which is applied in a manner similar to that used in the case of continuous elastic arches resting on elastic piers†, is (contrarily to what happens in the case of an arch system) to be discarded when the elastic system has more than two spans.

Ritter's analytical method may be followed in every instance. Evidently, the moment developed by the post will be equal to the difference between the two moments, one at the section of the girder immediately on the left, and the other at the section immediately on the right, of the support. This difference between each couple of the similar sections at each support causes, at each of these points, a sudden vertical step in the diagram of the moments, as is shown in Fig. 20.

* W. Ritter, "Der Kontinuirliche Balken", 1900.

† G. A. Hool, "Reinforced Concrete Construction", Vol. III, 1916.

Mr. Janni.

This calculation, in the case of a girder, as it has been assumed, is not a luxury of theory; it is purely a necessity of design. It should be made in order to take into account the real conditions of the elastic system. It is the aim of theory to simplify things as much as is consistently possible, but when a problem involves methods, which, perhaps, are still a little outside of the every-day routine designer's reach, engineers cannot sacrifice their pride to "rules-of-thumb". To disregard the moments in posts stiffly connected to a girder (and usually concrete girders are in this condition when supported by concrete posts) is an error of design which should be avoided.

The last point which the writer will take up is the graphical construction suggested by Mr. Jonson for the design of a three-span continuous girder.

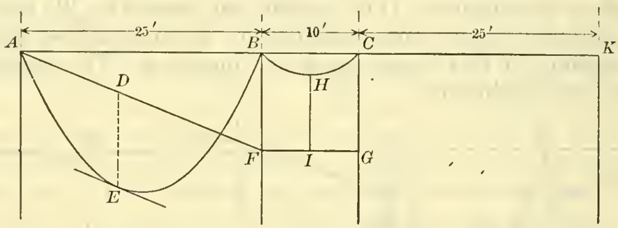

Fig. 21.

Fig. 21 is simply a representation of the graphical construction suggested by Mr. Jonson, and transmitted to the writer by him.

On page 775,* Mr. Jonson states:

"The correct method of calculating such a girder is much simpler than by the illegitimate use of the theorem of three or of four moments. Construct a static moment diagram on each span as if it were discontinuous. Then divide the diagram of the long span by a straight line in such a way that the positive moment at the middle of the suspended span is numerically equal to the negative moment in the double cantilever over the column. Then draw a horizontal line representing the negative moment across the middle span, and the area included between this line and the first moment curve will be the true moment diagram. The point at which the first straight line intersects the moment curve of the side span is, of course, the point at which the reinforcement should cross the center line."

It is granted that this graphical solution is "simpler" than the application of the theorem of three moments, or that which takes into consideration the moments due to the post connection; unfortunately, however, this is not a solution, but is something never heard of before. Suppose that the span, *A-B,* remains constant in length, and that the length of the span, *B-C,* increases gradually. According to this graphical construction, the moment at *B* will be always the same (that

* *Proceedings,* Am. Soc. C. E., for May, 1916.

is, B-F), since the post, B, does not move; therefore, no matter how long B-C becomes, its moments at its supports will be constant, and their value will be controlled solely by the preceding span, A-B. Mr. Janni.

Mr. Eddy's discussion may be divided into two parts: In the first he states that the fundamental equations of the paper are wrong, since they do not agree with Equations (1) of his discussion, which, as he says, are the equations for a flat slab in their most general form. In the second part he remarks that, since the mathematical working out of the formula is also wrong, the results do not deserve great confidence.

Before proceeding any farther with this part of the discussion, the writer wishes to ask Mr. Eddy whether he is sure that his Equations (1), as interpreted by him, are the correct moment equations for the flexure of a plate or slab, and that, as such, they "have been accepted universally as valid, and have never been disputed by any competent writer?"

Furthermore, is he sure that in these equations due consideration is given to shear?

If we take, for instance, the first of Equations (1), we note that it is the sum of two equations, namely:

$$M_1 = \pm E I \frac{d^2 z}{d x^2}$$

$$- K M_1 = \pm E I \frac{d^2 z}{d y^2}.$$

The first is the differential equation of the elastic line due only to the longitudinal deformation, by compression and tension, in the various fibers of the beam, caused by the moment, M_1; the second equation gives the algebraic additional deformation of the elastic line due to the cross-deformation of the same longitudinal fibers of the beam, as is shown by the presence in this equation of the ratio, K, and of the expression, $\frac{d^2 z}{d y^2}$.

Since, as is very well known, the first of these two equations is quite independent of shear, Mr. Eddy should have devoted a few words to the justification of his statement that, at least, the second equation contains shear. It would be very interesting to see how Mr. Eddy could discover the shear in an equation in which the second member is purely a differential geometrical expression multiplied by a numerical constant, E (which constant refers only to compression and tension), and by a geometrical (or numerical) quantity, I, and the first member contains a certain numerical quantity, K, due to tension or compression, and a moment, M_1, which has nothing to do with shear.

Mr. Janni.

An assertion such as that made by Mr. Eddy is very grave, and cannot be passed without being pointed out.

As a matter of fact, Equations (1), with the interpretation given by Mr. Eddy, are quite independent of each other as long as some kind of relation among the expressions, $\frac{d^2 z}{d x^2}$, $\frac{d^2 z}{d y^2}$, is not given. They represent the deflections of two beams which deflect, one under the action of the moment, M_1, and the other under the action of the moment, M_2, and this, contrary to what Mr. Eddy has asserted, is quite independent of shear; therefore, they are not general.

These beams, on account of the same notations, x, y, z, might be supposed to cross each other normally at some point of their spans.

Assuming, as it is legitimate to do, that they be applied to the ideal beams in our case, the writer will show that the fundamental equations of the paper agree with the equations as given by Mr. Eddy, and that the mathematical working out of the formulas, derived from the equations given by the writer, is correct. In fact, taking, for instance, the first of these two equations,

$$(1 - K^2)\, M_1 = \pm\, E\, I \left(\frac{d^2 z}{d x^2} + K \frac{d^2 z}{d y^2}\right)$$

we see that the term, $K \frac{d^2 z}{d y^2}$, of the second member refers entirely to the vertical deflection of the ideal beam, due solely to the lateral (or horizontal) deformation of the cross-section of the ideal beam in that part of the slab.

This lateral deformation has been logically stated to be zero, on account of the working conditions of the ideal beams of System a in connection with those of System b, therefore this equation, applied to the middle beam of one of the two systems, becomes:

$$(1 - K^2)\, M_1 = \pm\, E\, I \frac{d^2 z}{d x^2}.$$

This being the deflection at the end of the cantilever, the work of deformation of the entire cantilever, between the limits, 0 and $\frac{l}{2}$, will be given by:

$$L = \int_0^{\frac{l}{2}} \frac{1 - K^2}{E\, I}\, M \times \frac{1}{2}\, M \,.\, d\, x = \int_0^{\frac{l}{2}} \frac{1 - K^2}{2\, E\, I}\, M^2 \,.\, d\, x.$$

Substituting for K its classical form, $\frac{1}{m}$, we obtain,

$$L = \int_0^{\frac{l}{2}} \frac{m^2 - 1}{m^2} \times \frac{M^2 \,.\, d\, x}{2\, E\, I}.$$

which is identical with Equation (2) in the paper.

It is demonstrated, therefore, that Equation (2) is correct, and, of course, agrees with the equations given for this case of deflection. In exactly the same way we might proceed for the other equation of the system given by Mr. Eddy, when it is applied to the other middle beam of the other system of beams. Having demonstrated the correctness of the writer's Equation (2), it follows that Equations (10) and (11) are correct also. Mr. Janni.

The writer certainly is indebted to Mr. Eddy, as his erroneous remark has given the writer the opportunity of deriving his Equation (2) in an entirely different way.

It is rather interesting to observe that, though Mr. Eddy had found out that "The fundamental equations used by Mr. Janni differ from these [Equations (1) of Mr. Eddy] in reality only in one point, namely, by suppressing and leaving out the last term of each of them", he did not stop to think about the mathematical meaning of this suppression, but confined his investigation purely to a clerical check. He says: "Mr. Janni in his mathematical work has chosen to develop the subject by attempting to modify and apply the equations of Professor Fraenkel for beams. * * *."

This remark is preposterous. As a matter of fact, there are no such equations as "equations of Professor Fraenkel" on this subject, and the writer is very much surprised at the statement.

What Mr. Eddy calls "equations of Professor Fraenkel" are merely the equations on the deflection of a beam in their most general form, derived by applying the law of virtual work, which any good book on the subject reports, just to show that it is possible, by that method, to generalize the equations on deflection, in the same way as the theorem of three moments by this same law has been generalized and made applicable in the case, for instance, of a variation in the cross-section of a continuous beam.

Mr. Eddy, in making this statement, is crediting Professor Fraenkel with a paternity of which the latter never dreamed.

Mr. Eddy says:

"These errors in Equations (1) and (2) are curiously so related, the one to the other, that Equation (3) is the same as would be obtained were the alterations just pointed out made in Equations (1) and (2)."

It has been already demonstrated that Equation (2) is correct, and it will be shown presently that this is the case also with Equation (1).

Among the most remarkable theorems demonstrated by the law of virtual work, there is one, by Castigliano,* called "Theorem on the

* Castigliano, "Teoria dell' equilibrio dei sistemi elastici e sue applicazioni", Torino, 1879. The original Italian work is not available, but there is a French translation.

Mr. Janni. derivative of work". This theorem has demonstrated the correctness of the expression:

$$D = \frac{d\,L}{d\,F}.$$

It may be explained as follows: The displacement, D, of a point of an elastic system along the direction of an ideal force acting on this point, is given by the partial derivative, with respect to the applied ideal force, of the work of deformation of the entire system. Incidentally, it can be safely stated that this theorem and the peculiar form of the foregoing expression are familiar to anybody who has had even the slightest acquaintance with the theory of virtual work. It is hoped that this is enough to substantiate the strict correctness of Equation (1), without inserting in these conclusions a couple of pages of theory taken from some textbook.

Mr. Eddy furthermore states that there is no proof that the equation, $f\,\frac{I}{h} = (1 - K^2)\,M$, is given by any known theory. It will be demonstrated that the theory, on the writer's assumptions, gives this equation as correct. In fact, taking the equation, $e_1 = \frac{m^2 - 1}{m^2} \times \frac{f_1}{E}$, already given herein, and observing that $E\,e_1 = f$ and $f_1 = \frac{M\,h}{I}$, we may write:

$$f\,\frac{I}{h} = \frac{m^2 - 1}{m^2}\,M$$

which demonstrates that the general equation for the deflection has been given correctly by the writer. Mr. Eddy can hardly expect to have reported by theory all possible equations for all possible hypotheses; it is very often the task of the engineer to derive equations for each particular case.

Mr. Turner's Equations (1) and (2), with the interpretation given by him, are not "the fundamental equations of extensional stress and strain established a generation ago and accepted by Grashof and all authorities on the subject, since then".

In the first place, the general equations to which Mr. Turner refers are three, and not two, namely:

$$\left.\begin{aligned} E\,e_1 &= p_1 - K\,p_2 \\ E\,e_2 &= p_2 - K\,p_1 \\ E\,e_3 &= -(p_1 + p_2)K \end{aligned}\right\} \qquad (34)$$

They are obtained by considering the equilibrium of a small cube (element), two faces of which are always normal to the vertical plane of symmetry of the cross-section of a beam, and, at the same time, are parallel to one of the two "principal stresses" reacting at that point;

Mr. Janni.

it follows that the other two faces of the cube will be parallel to the other "principal stresses".

Let A-B (Fig. 22) be the vertical profile of a cross-section of a beam, and O the position (altitude) of its neutral axis.

The position of the elemental cube at this point is shown, as well as the directions of the "principal stresses"* acting on that cube at that point. (If p_1 is assumed to be negative, then p_2 is positive, and *vice versa.*)

It being known that the directions and values of the principal stresses, changeable with the altitude of the point of the cross-section at which we consider the cube, it follows that only at the top and bottom of the section this cube has two faces horizontal, and that it revolves through 45° in passing from O to A, and through an additional 45° in passing from O to B.

Furthermore, it is known that the third equation of this system, which refers to the cross deformation of the elemental cube, is zero only when these equations are applied to the cubical element at the neutral axis of the beam, because then, and only then, $p_1 = - p_2$, or $- p_1 = p_2$. Mr. Turner can easily verify this by examining the circular diagram theory, as written by K. Culmann.†

Mr. Turner's attention is called to the fact that these stresses, p_1 and p_2, lie on a vertical plane normal to the cross-section of the beam, and not on a horizontal plane, as he states, which is quite different. He will notice, also, by inspecting Fig. 22, that these stresses cannot be made zero where and when he pleases; they are zero only when the circular diagrams, previously mentioned, make them so.

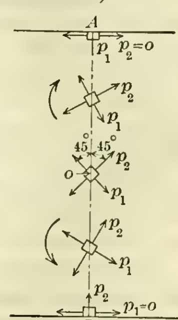

FIG. 22.

These equations, therefore, with the correct interpretations, as given by the writer, are to be regarded as the general equations of equilibrium of a beam, and, as such, they are accepted, of course, by everybody.

Neither Grashof nor any other authority would have accepted the equations, as given and interpreted by Mr. Turner, as general equations for the deflection of a beam, and the use of his illustrious name in this connection is not altogether commendable.

There is also another remark to be made regarding the interpretation of the general equations of the equilibrium of a beam. The writer notes that Mr. Turner applies these "would-be" general equations for this case of equilibrium to a plate, by simply changing the word "beam" to "plate", without thinking that theory cannot be made to apply by simply substituting one word for another. There is great static difference between the equilibrium of a plain beam and a plate.

* These "principal stresses" are sometimes designated improperly "diagonal stresses".

† "Die graphische Statik." Zurich, 1866–75.

Mr. Janni. Equations (1) and (2), as given by Mr. Turner, are simply Equations (26) and (27), as given by the writer; that is, the equations of equilibrium (not general) applied to the particular case under discussion, as has been shown already in this closing discussion, with the additional difference that the elemental cube, in this case, is assumed to have always two faces horizontal, no matter at what altitude it is considered. So that, when Mr. Turner says: "if p_2 is zero, as it would be in a beam", he is quite wrong. As a matter of fact, in an ordinary beam (and Mr. Turner discusses this kind of beam) the value of his p_2 is never zero, except at the plane of the neutral axis.

The fact that it is never zero in an ordinary beam, though in the ideal beam, as chosen by the writer, it is logically constantly zero, constitutes the radical difference between the two cases of deflection (common beam and ideal beam).

In considering his case of a plate, Mr. Turner states:

"Assuming that K (Poisson's ratio) is zero, it has been demonstrated that the work done in a circular direction is equal to that done in a radial direction. Now, radial deformations alone determine the vertical position of the cantilever plate, and though the circumferential deformations necessarily accompany radial deformations, they provide a means of storage of energy which is not involved in nor determines the vertical deflection".

In the first place, the coefficient, K, of Poisson is far from being zero, therefore, the resulting demonstration, to which he refers, may be interesting, but its conclusion is untrue.

In the second place, does Mr. Turner really mean what he says about the storing of energy? Does he really mean to say that in the theory of elasticity it is quite possible to have work without the corresponding displacement? In other words, if the writer understands rightly, the expression for the work, going entirely by definition, is given by $L = F \times \delta$, in which L is the work, F is the applied force, and δ is the elastic displacement, Mr. Turner states that, by assuming $\delta = 0$ the quantity, L, is not zero. The writer prefers to believe that Mr. Turner did not mean that; although he said so repeatedly, in different ways.

He says, furthermore: "Now, the relative stiffness of the continuous and simple beam, is known by theory to be as five to one". This statement is not exact; the ratio between the deflections referred to is correct only in the case of a beam rigidly supported at its ends, and one freely supported. In dealing with a continuous and a simple beam, the ratio given by Mr. Turner is not exact, but varies according to the hypothesis of loading of the spans.

Apart from this inexactness in Mr. Turner's statement, however, we can see by the statement itself that he makes comparison with a beam with fixed ends, when it is known that such cases of equilibrium

are discarded from reinforced concrete design; neither does he state whether, in his "numerous experimental results", he used the partial or total loading. Mr. Janni.

The writer must confess that he is unable to follow Mr. Turner in his "photographic" conception. It may be, however, that his copper half-tone plate comparison may be very interesting to the reader who knows something of this subject; the writer can see neither the plate nor the screen.

At this point of his discussion, Mr. Turner enters another field: "shearing rigidity and flange rigidity". Judging from his nomenclature for this particular internal stress, it seems that he makes a difference between shearing rigidity and what he terms "flange rigidity". It is difficult for the writer to understand, from this new phrase, "flange rigidity", whether Mr. Turner means the resistance of the flange to shear, or some other internal stress just discovered. However, if he agrees with the writer that, usually, exclusive of compression (tension) and shear in the deflection of a beam, there is no other internal stress to be considered, then the writer will conclude that this "flange rigidity" is nothing but the resistance of the flange to shear.

This being the case—as it must be, according to the elementary principles of theory—the shearing rigidity and flange rigidity are simply plain shear in both cases, and therefore all theorems concerning shear may be applied.

Mr. Turner says:

"Another matter which is very puzzling to many is the fact that the mechanics of a solid is such that ordinary rules of statics do not apply, that is, the rules of statics as applied to the separate members of framed structures are not here applicable."

As an example of this he states that, "under pure statics, a force in one direction cannot affect the magnitude of the force at right angles thereto", but in mechanics "that is not the case", since here the "deformation in one direction under a given force affects and influences the deformation produced by a force at right angles thereto". This—to say the least—shows a peculiar confusion between forces and deformations, as well as a quite new conception of statics.

In the first place, all the rules of statics, being mathematically true, stand, no matter whether they are applied to a separate member or to a framed structure; there is not, and never will be, it can be stated with mathematical certainty, a single problem in mechanics where these rules will not apply, as Mr. Turner wrongly states.

It is true that sometimes the rules of statics are not sufficient for the solution of certain problems, for instance, the elastic arch, the continuous girder, etc., and then help must be obtained outside of

Mr. Janni. statics; but this does not mean that these rules do not apply. It is no wonder, therefore, that many are very much puzzled by such a statement as Mr. Turner has made.

Secondarily, though the example he cites as a proof of his assertion does not mean anything bearing on the assertion itself, it shows an alarming confusion in Mr. Turner's mind between deformations produced by force and by components of that force; between causes and effects.

The deformation produced by the forces, p_1 (Fig. 14), affects that produced by the forces, p_2, but this does not mean that the forces, p_1, are the components of the forces, p_2, or *vice versa*. The forces, p_1, have no partial or total components along the forces, p_2, and this is true here as well as in plain statics; the same may be said of p_2 with respect to p_1.

From the foregoing statement of Mr. Turner, it can be safely said that, to the realization of perpetual motion, is a very short step.

Taking up the matter of distribution of shearing stress, both in a beam and in a slab, Mr. Turner says:

"In the beam horizontal shearing stresses act only in horizontal planes, but in the slab, with its double change in curvature, horizontal shearing forces act in vertical planes as well."

Apart from the fact that the double change in curvature of the slab has nothing to do with the distribution of this internal stress, it may be said that the foregoing statement is altogether wrong. Mr. Turner undoubtedly knows that at any point of the cross-section of a beam there is a horizontal shear and a vertical shear, and these two stresses are equal, this conception being very elementary. How, therefore, can he say that in a beam there is no vertical shear? If he, reversing the entire theory on shear, does not admit this vertical shear, he does not know that without it the internal stresses, taken altogether, cannot be in equilibrium.

Concerning the slab, however, he concedes that there is a vertical shear, but that vertical shear is there on account of double change in curvature. That is equivalent to saying that, if the slab has no double curvature or has more than a double curvature, the vertical shear will disappear.

Whatever Mr. Turner's ideas are regarding this matter of shear, it may be stated that, as a matter of fact, the vertical shear in the slab is always there when there is horizontal shear. In other words, the law of the distribution of shearing stresses, along the horizontal and vertical faces of the elements of a beam, holds good also in a slab, as it must.

It is true that in a square slab, for instance, there are lines along which there is no vertical shearing stress, but, accordingly, along those

same lines there is no horizontal shear either; of course, this happens when the slab is assumed to be uniformly loaded. Mr. Janni.

Mr. Turner, the writer is sure, must know that the theory of shear, holds good for beams, or for slabs, or for arches. This theory is quite independent of the external shape of the solid. The only assumption—made at the beginning—is that the two cross-sections, A-B and A'-B' (Fig. 23), of a solid shall be so near that, even if the whole solid has variable shape, these two sections may legitimately be considered as equal.

The single or double curvature mentioned by Mr. Turner is a deformation brought about by the application to the solid of external forces, and, as such, like all elastic deformations, they have no influence whatsoever on the law of the distribution of the internal stresses of the solid.

Sometimes these deformations, as in the case of arches, bring out additional stresses which are to be added properly to the former ones; but this does not destroy, nor modify in the least, the manner in which the former ones are distributed in the interior of the solid. Therefore, speaking of double curvature of a solid as affecting the law of distribution of internal stresses is erroneous.

FIG. 23.

From Mr. Turner's remarks concerning the two glued or bolted planks and the cured concrete slab, it appears that he considers all the strength of a beam and of a slab to depend on the shearing stress at the neutral plane of these solids.

As a matter of fact, the shear at the neutral plane (as well as that at any other plane) is necessary to the resistance of these solids, but is not more necessary than tension and compression. All these internal stresses have their rôle; all are necessary, but one is not more necessary than the other. Take the case of the two planks; after they are bolted together it is found (correctly) that the resistance of this new beam is twofold, and from this fact Mr. Turner concludes that this is due to the shear obtained along the neutral plane; accordingly, he speaks of its great importance in the resisting quality of the beam. He, however, does not stop to think that, if this new beam is cut across vertically (for instance, at its center) from the bottom up to the glued plane, or is cut with a V-shaped notch from the top down to the glued plane, it, with all its shearing rigidity, is worth no more than one of the planks of which it is constructed, as far as bending is concerned. Is there any reason, therefore, for giving to the shear rigidity so much preference?

The writer has taken up simply the important theoretical points brought up by Mr. Turner, but has not discussed either his criticism of the paper, or his eulogy on a certain theory on flat slabs written by Mr. Eddy.

Mr. Janni.

As Mr. Turner has not shown any particular care in his quotations from theory, and has not been clear in his conceptions of the strength of materials, the writer is of the opinion that his criticism of the paper has no bearing whatever.

Therefore, if the "most gratifying concordance between deflections and stresses", as Mr. Turner states, has been found on the strength of the kind of theory quoted by Mr. Turner in his discussion, is there any "more cogent reason" for stating that the theory he is supporting is not a theory but merely ordinary guesswork, and as such should be objectionable, for it is unsafe?

Will engineers dump and bury forever a public patrimony, called theory, in order that Mr. Eddy's theory may stand up?

No one will have any hesitation in his choice.

In reply to Mr. Mensch's remark, that the writer's theory is misleading because the moments calculated by it are not the same for all strips, the writer wishes to state that he never meant that the reinforcement in the entire slab should be computed according to those values. It is stated in the paper that the intention is to calculate the maximum in each direction only, and for this reason alone he selected the middle strips.

Knowing the maximum values of the moments at the center of the middle span of each middle beam, and their values at the support points, the arrangement of the reinforcement is an easy matter.

Since the remaining part of Mr. Mensch's discussion, like a good part of several of the others, seems to be a discussion of Mr. Jonson's remarks, to which the writer already has answered at length, it is thought expedient to disregard that part in order not to present, practically, the same arguments.

Mr. Marsh brings out the fact that Equation (12), for ratios of $\frac{l_1}{l}$ greater than $\frac{5}{3}$, gives a transverse coefficient greater than unity and a minus quantity for the longitudinal coefficient. This he points out as a defect of this formula.

Several formulas in engineering mathematics, as Mr. Marsh undoubtedly knows, need logical interpretation before proceeding to apply them.

Take, for instance, the very formula in which the coefficient of Poisson has its origin, that is:

$$\left(1 + 2\,\frac{e}{m} - e\right) A \,.\, \Delta\, x = V'$$

where: e = stretching of the fiber per unit of length;

m = coefficient of Poisson;

A = area of the cross-section of the fiber;

$\Delta\ x$ = its length;

and V' = volume of the stretched fiber.

Mr. Janni.

In order to obtain our result, we must observe first that the volume of the stretched element cannot, logically, be increased by the actions of the two tensile forces applied to it; accordingly, we are able to put the condition that $\frac{e}{m} < \frac{1}{2} e$, from which we derive that the value of $\frac{1}{m}$ is between 0 and $\frac{1}{2}$. Without this logical assumption, we would never be able to determine the limits of $\frac{1}{m}$. Indeed, we might come to the absurd conclusion that the volume of the fiber, $A \cdot \Delta x = V$, increases under the action of extensional forces.

The formula of Euler is another instance. Mr. Marsh undoubtedly knows that the indiscriminate use of this formula may lead to absurdity, due to its nature, as it is not a purely mathematical formula but one of elasticity.

A formula of elasticity is to be regarded as absurd when at each and every stage of its values it brings out absurd results, or else it is derived on absurd assumptions.*

The writer, however, is indebted to Mr. Marsh for having pointed out this fact, as it has thus given an opportunity to explain fully this point also.

Mr. Marsh remarks also that the introduction of Poisson's ratio is doubtless essential to this problem, but he has misgivings regarding its practical utility and accuracy.

It can be pointed out that the little justified doubt concerning the accuracy of the coefficient of Poisson does not destroy the correctness of its introduction in this problem. There is an incontestable physical phenomenon, which happens in this case of deflection, and as this was recognized as essential by the writer and also by Mr. Marsh, it must be taken into account.

The omission of the coefficient of Poisson in any flat slab theory, means the undermining of that theory.

The writer regrets that Mr. McMillan has devoted his valuable time entirely to the discussion of the points brought out by Mr. Jonson. It is true that if those points had cast a new light on the whole theory of reinforced concrete they would have undermined also the solution of the problem proposed and solved by the writer, but Mr. McMillan knows very well that those points were not new by any means, and that their solution was already a matter of fact, and this apart from the fact that the solution proposed by Mr. Jonson lacks any serious mathematical support, as has been shown.

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* In pure mathematics we have a similar state of affairs in the solution of equations above the first degree. Mathematically speaking, all the roots of an equation are true and solve the same equation; but how many of those roots must we discard because they lead to absurd conclusions in our problem? Does this mean that the theory of the solution of equations is wrong?

Mr. Janni. As a general impression of the various discussions on this paper, it can be said that only those by Mr. Goodrich, and by Mr. Godfrey took up the important point brought forth by this problem, namely, the great variation of the moments in a continuous slab determined by the yielding of the supports.

It seems to the writer that attention has been centered only on the formulas for the design of a flat slab rigidly supported, which formulas, after all, were purely incidental to the problem.

Apart from the fact that these formulas, as far as the difficulty of the problem has allowed, have been demonstrated to be correct both in their conception and from a mathematical point of view, there is the fact that, even applying other formulas, theory would have given the same results, as far as difference of moments in both hypotheses is concerned.

The writer, whose professional activity is not narrowed down to the designing of reinforced concrete flat slabs, was unaware that there could be such a thing as "A flat slab specialist", but, after this discussion, he must say that, if there is such a specialty, its theory needs some decided improvement.

In this closure the writer cannot refrain from expressing his opinion concerning technical discussions.

There is no doubt that a discussion on a scientific question is more apt to bring to light important truths than an ordinary publication on that subject, and, in the opinion of the writer, a sound, well-thought-out contribution to the subject in question is not only welcomed by the interested public, but more so by the author of the paper himself. Remarks and opinions on a technical problem have a bearing upon it, if they are supported either by theory or by logic, but when they are, so to speak, supported only by a sadly crippled or misunderstood theory, such discussions then become useless and somewhat ridiculous.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

TUNNEL WORK ON SECTIONS 8, 9, 10, AND 11, BROADWAY-LEXINGTON AVENUE SUBWAY, NEW YORK CITY

Discussion.*

By Messrs. T. Kennard Thomson, John H. Myers, H. G. Moulton, Robert Ridgway, and C. V. V. Powers.

T. Kennard Thomson,† M. Am. Soc. C. E.—Mr. Werbin is entitled to hearty thanks for his excellent presentation of a very interesting subject. Mr. Thomson.

The speaker cannot help contrasting the difference, in many ways, between the construction of a rock-and-mud tunnel, on which he was engaged 32 years ago, and this up-to-date subway. This is exemplified by the difference between a small tallow candle and a large electric searchlight.

The success of the blasting operations on this work might also be contrasted with a case in New York Harbor some 15 years ago, when a coffer-dam was built as far out as it was considered economical, and the rock excavated inside the coffer-dam in the dry. From the finished excavated space (inside the coffer-dam), some fifty holes were drilled into the rock to be removed, outside the coffer-dam lines.

To ensure success the contractor secured a man from the explosives manufacturer to load the holes and connect the exploders in such a manner as to make a complete circuit. As the current would have to travel through this circuit, it seemed impossible to have a hitch; but only three or four exploders (at different parts of the circuit of fifty) were set off at the first attempt. The wires were then connected again, and a number, but not all, of the remaining charges went off. This naturally put the rest of the work in a very uncertain condition.

In order to ascertain the cause of the failure, the speaker took twenty-five exploders from the same stock, connected them up in the

* Discussion of the paper by Israel V. Werbin, Assoc. M. Am. Soc. C. E., continued from October, 1916, *Proceedings*.

† New York City.

Mr. Thomson. same manner as before, but without the dynamite, threw them into the water, turned on the current, and only four (at intervals) exploded. The remaining twenty-one were again connected up, and all went off together, showing that some of them were just a trifle quicker than the others.

The author speaks of the considerable quantity of extra rock excavation which the contractor was obliged to do without compensation. This is not equitable, but it seems to be difficult to draw up a contract which will allow for these changes; and, on public work, very few engineers dare to be just, against the terms of the contract and specifications, as they would be accused of graft, etc.

This refusal of the authorities to give the engineers a chance to use their own judgment, however, is costing the country millions of dollars, as the contractors have to bid higher than they would otherwise. As an example, an engineer who, in his time, had a reputation of the very highest, and did an enormous amount of work, got the reputation of refusing to allow any change in his plans and insisting on refinements which did not improve the job. The result was that his clients paid far more for what they got than they would have done otherwise. For instance, the manager of a large manufacturing concern once told the speaker that he always figured work for that engineer just as he would for anybody else and added 25% to the price to cover such arbitrariness.

Mr. Myers. JOHN H. MYERS,* ASSOC. M. AM. SOC. C. E.—The speaker thinks that engineering literature contains many references to tunnels which approximate the size of the two-track sections described in this paper, and that he is correct when he says that there are few, if any, such references to tunnels similar to the four-track sections. He refers especially to the tunnel of varying cross-section by which is accomplished the transition from double-deck (or two tracks over two) to four tracks abreast between 98th and 102d Streets. He thinks, therefore, that Mr. Werbin has done a valuable service in compiling this accurate and complete record of this work.

There is one theme that runs all through the paper which should be emphasized, and that is the character of the design which permitted what may be termed sectional construction. By this is meant the design which allowed the tunnel lining to follow quickly after the excavation and enabled the constructor to excavate and line part of the tunnel before excavating and lining the remainder. The methods of construction which such a design made possible are illustrated in Figs. 1, 15, 16, 17, 18, 25, and 29, and Plate IX. It is the speaker's opinion that this design aided materially in the successful completion of this very unusual work through a portion of the city which presented many natural difficulties.

* New York City.

The fact that a structure of the magnitude of that described has been built through the heart of the city without material interruption of its mode of living, or of its varied industries, is in itself worthy of note, and the record of the methods used in bringing this about, which the paper provides, is, the speaker believes, of permanent technical and historical value. Mr. Myers.

H. G. MOULTON,* Esq.—The tunnels on Lexington Avenue, especially the double-deck sections, approximately 40 ft. high and 40 ft. wide, are quite unusual in size, from a civil engineering standpoint; yet they are small in comparison with underground excavations required in mining operations. The work on these sections presents problems more nearly comparable to metal mining than those encountered anywhere else on subway construction in New York City. Mr. Moulton.

In mining large bodies of ore, it is often necessary to carry a stope, for a width in excess of 100 ft., to a height of 100 ft. (the usual distance between levels), and for a length of several hundred feet on the strike of the vein, and to carry the walls, roof, and face of the excavation on timbers. As the work on Lexington Avenue is so similar in type, though on a much smaller scale, it is interesting to consider the possibility of adapting to work of this kind the methods used in extracting irregular ore bodies, the dimensions of which are too large to permit the walls and roof to stand for any length of time without support.

There are two marked differences between the excavation methods described in this paper and those which would have been used under metal-mining practice. The first difference is in the method of attack—the use of the top heading instead of a bottom heading, as in mining operations. The second is in the method of timbering the opening—I-beams, segmental sets, etc.

In the very early days of western mining development, it was common practice to remove ore bodies in very much the same manner as that described in this paper. The method is known as underhand stoping, and consists of carrying the upper level of the excavation in advance of the lower, and following in successive levels with the excavation of the bench. As mining methods developed, it was realized that this was the least economical way of attack, and it was abandoned in favor of overhand stoping or, in other words, bottom heading work, in which the lowest part of the excavation is carried well in advance and the back is taken down in successive slices, stepping back consecutively toward the roof. This method has the advantage of less shoveling and also of cheaper breaking, as the rock is broken from an under-cut horizontal face at less cost than from any other position, and also because the drilling can be done with the most efficient types of drills—the so-called stope hammers or buzzers.

* New York City.

Mr. Moulton.

In order to hold the walls and roof and keep the men close to the working face, timbering is placed in sections as the work progresses. The usual dimensions of the timber sets common in metal-mining practice are 7 ft. high, 5 ft. wide between posts, and 5 ft. longitudinally between bents or adjacent rows of posts. The posts, caps, and girts are all framed to exact lengths and provided with horns in daps so that connection is secured for each member of the set in every direction. The rock is broken out in small sections, say, 5 ft. square and 7 ft. high, and another set of timbering is placed. On all slices above the bottom heading, the new post rests directly on top of one of the posts set in the bottom heading, and the cap and girt join with the set at the side and to the rear. In this way the entire mass of rock is removed in a series of inverted steps in such a manner that not more than 5 ft. in either direction is without timber support at any time. The probability of an extensive rock fall is eliminated, and it is possible to work exactly to the pay line of the excavation.

To apply square-set stoping to such an operation as that described in this paper, the first step would be to sink a shaft at one side of the excavation and drive a bottom heading in each direction in the lower corner of the section nearest to the shaft. This bottom heading would be continued through to the next shaft and timbered continuously with the foundation or sill floor timbers of the square-set system. At different places along the heading, the stopes would be started, widened to the opposite side of the section, carried up to the roof, and then continued in both directions until several hundred feet had been opened and timbered. After this, a start would be made on steel erection, the timber sets being pulled out row after row, after alternate bays of steel had been erected and concreted between them. Where no heavy pressures had been developed, the sets would be removed quite readily after knocking out the side and top blocking and wedging. Where heavy pressures had developed from loose ground, it would be necessary to do considerable work with axe and saw on the bottom posts, and ruin part of the timber. Yet, even under the worst circumstances, it is possible that 75% of the timbers could be recovered and used over and over again as the work progressed.

As to the cost of this method, ore is mined on an extensive scale in various districts at costs ranging from \$1.50 to \$2.50 per ton by square-set stoping at reasonable depths, exclusive of any items corresponding to cost of plant or contractors' profits. This would be equivalent to about \$3 to \$5 per yd. The timber required would be approximately, 30 ft. b. m. per cu. yd. of material taken out, and, with timber at \$60 per ft. b. m. in place, the cost would amount to \$1.80 per cu. yd. Considering that most of the timber would be used over and over again, and also that round timbers would be the most advantageous to use, and much less expensive than sawed stuff, it is probable that \$1 per cu.

Mr. Moulton.

yd. would represent the maximum cost for timbering. Against this additional cost there would be certain credits, as compared with carrying the excavation open and with no timbering at all. One such credit would be in cheaper breaking and mucking costs, due to shooting the rock down from an under-cut face and catching it on heaving blocking of poles resting on the caps of the timber sets. It could then be shoveled into chutes and drawn into cars in the main bottom heading. Another saving in cost would be realized by working exactly to the pay line, and saving the excess cost of hauling out irregular masses of material, broken away outside of the section, and afterward concreting and back-filling these spaces. In blocky ground, such as was often encountered on Lexington Avenue, it is probable that the credits from the items mentioned would more than offset the additional cost of $1 per cu. yd. for timbering, so that this method might well be cheaper than the ones used.

As to the question of safety, there can be little doubt that full square-set timbering would have the advantage. The great principle involved in keeping rock excavation safe is to have the smallest possible quantity of ground standing without support. On Lexington Avenue, this was done by building the finished structure in sections; but the same thing could have been accomplished, and even greater protection secured, by putting in the timber in small sections and having only the extent of one set open at any one time. Then, the steel structure could be built in its entirety between the timbers at any distance desired behind the face.

As to speed, all the advantages are with the bottom-heading method of attack, as it is possible to open up as many faces as desired dependent only on the hoisting capacity of the shafts.

It is well recognized that even the worst ground may be held with comparative ease before any movement starts, but if once it starts, it may demolish any timbers that can be put in. Close timbering, to prevent the initial slip, may mean all the difference between absolute safety and serious collapse. The wedging and arching action of blocks of rock in unsound ground, together with the frequent resistance on seams, and probably to a certain extent atmospheric pressure, renders valuable assistance to the timbers in holding the ground, and the timber system should provide for this by preventing the initial movement which may destroy all these valuable allies.

As to the timbering methods used in unsound ground on Lexington Avenue, and described in this paper, the speaker is of the opinion that although they served their purpose in giving protection while the work was being carried on, nevertheless, they were unnecessarily expensive and inefficient, as compared with the usual mine-timbering methods. The segmental set, for example, which is used so widely in large tunnel headings, represents the most inefficient and uneconomical manner in

Mr. Moulton. which timber can be used. It usually comes down at the joints long before the timber can develop its strength as an arch, and wherever heavy ground is encountered in the roof, the segmental sets must be reinforced with longitudinal horseheads under the top cap and radial posts at the joints. About all that segmental sets will accomplish is the prevention of spalling and light rock falls from the roof. Where really heavy ground is encountered, as in extracting ore by the caving system, very different methods of timbering are used. Good examples of this are to be seen in some of the leading mines in Arizona, where the ore is extracted by honeycombing the lower part of a block with tunnels and then shooting out the adjacent supporting pillars, so that the entire block drops 6 or 7 ft. and is crushed by its own weight. To keep the main haulage drifts open below such a block of ground, they are timbered with long flat caps reinforced with a short cap in the center, blocked against knee-braces resting on short posts within the main posts of the set. This type of set is so much superior to any attempts to obtain arching action through segmental timbers that it is surprising it is not generally adopted in timbering railroad tunnel headings through heavy ground.

There is a general principle involved in timbering rock excavations, namely, that small posts acting in compression form the most economical method of support. Mine timbering should be placed in small units, and the use of timber in beams or in arches should be avoided as far as possible. There is also a great advantage in smaller units, in that they are easily placed and with fewer men.

The use of many of the methods shown in the paper, such as long I-beams, cribbing built up to support long beams and packing above, is reminiscent of descriptions of the early attempts of metal miners to support ground prior to the development of square-set stoping. The largest timber available was often taken into the mine, and great posts were built up by splicing, perhaps to 60 ft. or more in length. Some of the stopes in the old Elkhorn Mine, in Montana, furnish a good example of these massive long stulls and posts. It requires many times the quantity of timber to work in this way that square-set stoping in small units would call for. Furthermore, the work is not as safe, and the labor required in handling these great units is excessive, as compared with that needed to place the smaller timbers. The same argument applies to the use of I-beams in underground work. Had the miners of a generation ago been able to obtain 24-in. and 36-in. I-beams, they would probably have stuck some of the stopes full of them in desperate attempts to span wide openings and carry the roof without posting support, but they would have soon abandoned them as they did their attempts to splice and build up long posts and beams.

The time required with the mining methods described would depend entirely on the number of faces opened. In the Butte District, which

is one of the best examples of square-set stoping in mining operations, well in excess of 10 000 cu. yd. of material are removed daily, from depths ranging from 2 000 to 2 800 ft. below the surface, and the daily extraction is varied in strict accordance with the ore requirements of the smelters, by increasing or decreasing the number of men at work on the various stoping faces. If such a method were applied on a job like the Lexington Avenue Subway, it would be merely a matter of carrying the bottom headings clear through and attacking at as many places as desired. The work could be speeded up or slowed down by opening more faces and operating more drills, or by shutting down on different faces. Mr. Moulton.

The whole subject, of course, is quite academic at the present time, because the Lexington Avenue Subway is finished and practically ready for operation. The work there was splendidly done, and the completion of the finished structure in its present form, under the difficult conditions encountered, was a feat for which the Bradley Contracting Company and the Engineering Department of the Public Service Commission justly deserve the fullest measure of congratulation and appreciation. Nevertheless, Lexington Avenue was about the only place on the New York subway construction where metal-mining methods might have been applied extensively with advantage, and this paper, therefore, makes pertinent a general discussion as to comparisons of such methods with those which the contractors adopted.

Robert Ridgway,* M. Am. Soc. C. E.—It would seem from a question asked during the discussion of this paper that the author has not made plain the practice followed in loading and firing the heading holes. Only those holes were loaded which were to be fired in one shot. This was also the practice in the headings of the City Aqueduct Tunnel of the Catskill Aqueduct, and is far safer than the method formerly used on some works in the vicinity of New York City, which was to load the whole face before firing any of the holes. Mr. Ridgway.

The author has referred to the presence of streams crossing the line of Lexington Avenue at 57th Street and at 75th Street, where soft ground was encountered in the tunnel headings. These streams, of course, indicated valleys in the surface of the country before the streets were graded. These and similar streams along the line of the work added greatly to the difficulties of construction. In some cases, the flow of these streams had been taken care of by roughly built stone culverts, but, in other instances, the street grading had been done without making any provision for the flow, and the water was allowed to flow through the rock back-fill, eventually finding its way into the sewers, or the East River. Relative to this matter, attention is called to the value of the topographical map of Manhattan Island, published in 1874 by Gen. Egbert L. Viele, as an aid to those doing

* New York City.

Mr. Ridgway. sub-surface work. This map, popularly known as the "Vielé map", shows the old watercourses and swamps quite accurately, and whenever particularly bad ground was encountered in subway work, the reason for it was usually indicated on this map. An engineer engaged on foundation work in New York City told the speaker that whenever he is called on to make a special investigation and report on such work, he looks at the "Vielé map" to ascertain whether or not there was an old stream or swamp near the foundation in question.

The problem to be met by the construction engineers in the work described was a most complicated and difficult one, as a reading of the paper shows. The speaker doubts whether a tunnel more difficult to construct has ever been built in a narrow city street than the one between 99th and 102d Streets. That it was completed successfully, without serious accident of any kind, is cause for congratulation, and indicates the care with which it was supervised. The speaker has an intimate knowledge of this work and is glad to testify to the faithful and intelligent direction of it by the Division Engineer in charge, John H. Myers, Assoc. M. Am. Soc. C. E.; the Assistant Division Engineers, John H. Madden and I. V. Werbin, Associate Members, Am. Soc. C. E.; and the Assistant Engineers in charge of the several sections of construction. Under Mr. Madden the work was begun and well advanced. When he was transferred to other work, he was succeeded by Mr. Werbin, who, up to that time, had been Assistant Engineer on one of the four sections. Mr. Werbin is well fitted to describe the work, on account of his close connection with it and the very careful attention which he has given to all its details of construction.

Much credit is also due the Bradley Contracting Company, the Contractor for Sections 8, 10, and 11, and P. McGovern and Company, the Contractor for Section 9.

There was a large excess of excavation outside of the tunnel lines on the sides and top, and, in order to protect the work and prevent loose rock from coming down, the thickness of the concrete was increased and the walls thus strengthened. Some of the contractors expect to receive compensation for this extra concrete, but none has yet been paid.

Mr. Powers. C. V. V. Powers,* M. Am. Soc. C. E.—Referring to Mr. Ridgway's remarks about the Vielé map: In the course of some investigation at the office of the Bureau of Street Openings, the speaker found original maps and surveys much older than the Vielé map. They are interesting and valuable as giving first-hand information in very considerable detail concerning old surface conditions. Any one desiring to consult them can no doubt do so by making proper application. Much of the information contained in the Vielé map was probably taken and condensed from these earlier drawings.

* New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

EARTH PRESSURES: A PRACTICAL COMPARISON OF THEORIES AND EXPERIMENTS

Discussion.*

By Messrs. William Cain, G. M. Braune, and F. N. Menefee.

William Cain,† M. Am. Soc. C. E. (by letter.)‡—The author refers to Ketchum's "Walls and Bins" for the writer's theories of earth pressure. The statement there is incomplete, as the writer's theory relative to the "limiting plane" is not given in that book.§ The reason for introducing this conception will be made plain from the following. Mr. Cain.

In Fig. 25, let $21O$ represent the free surface of an unlimited mass of earth, subjected to no force but its own weight, $2O$ being the line of greatest declivity, making the angle, i, with the horizontal. AO represents a vertical plane perpendicular to the plane of vertical section, $A2O$. Rankine has shown (Applied Mechanics, Arts. 125, 195) that the earth thrust, E, on the vertical plane, AO, acts parallel to $2O$, or to the free surface.

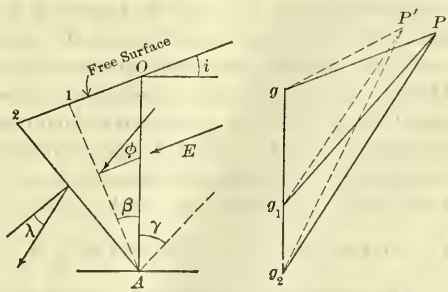

Fig. 25.

* This discussion (of the paper by L. D. Cornish, M. Am. Soc. C. E., published in August, 1916, *Proceedings,* but not presented at any meeting of the Society), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Chapel Hill, N. C.

‡ Received by the Secretary, October 9th, 1916.

§ It is to be found in the writer's "Practical Designing of Retaining Walls" (D. Van Nostrand Co.), pp. 58–61, and in a more complete form in his "Earth Pressure, Retaining Walls and Bins", pp. 38–42, recently published by John Wiley and Sons. The latter book will be referred to in this discussion by the letters "E. P.".

Mr. Cain. For the case supposed, there are two planes of rupture, shown by the dotted lines, which make angles, β and γ, with the vertical.* The thrust on the plane, $A1$, can be found by combining E, acting one-third of AO above A, with the weight of earth, $A1O$, the resultant making the angle, ϕ, with the normal to $A1$, as $A1$ is a plane of rupture. Similarly, the resultant thrust on a plane, $A2$, is found by combining E with the weight of earth, $A2O$. Suppose this resultant makes the angle, λ, with the normal to $A2$. We always have $\lambda < \phi$ (E. P., p. 38). The force diagram is shown to the right, Pg (to scale) being equal and parallel to E, gg_1 vertical and equal to the weight of $A1O$, and gg_2 vertical and equal to the weight of $A2O$. Thus, Pg_1 is the thrust on $A1$, making the angle, ϕ, with its normal, and Pg_2 is the thrust on $A2$, making the angle, λ, with its normal.

Now, in place of an unlimited mass of earth, as before, consider the earth limited by the retaining board, $A2$, which may likewise represent the inner face of a retaining wall extending to its left; and, for simplicity, take $\phi' = \phi$. It will now be shown that we cannot assume the thrust on the wall, $A2$, to make the angle, $\phi' = \phi$, with its normal and compute the thrust by the usual formulas involving wall friction. In fact, in order that λ should equal ϕ, the graphical method (E. P., Fig. 10 and p. 38) shows that the thrust on AO must lie nearer the vertical in direction and have a less horizontal component than before. Therefore, on drawing g_2P', making the angle, ϕ, with the normal to $A2$, some line, $P'g$, lying above Pg, and having a less horizontal component than Pg, can be supposed to represent the thrust on AO. But, now, the resultant, $P'g_1$ on $A1$, lies nearer the vertical than Pg_1 and thus makes an angle greater than ϕ with the normal to $A1$. Hence, equilibrium is impossible. Therefore, λ cannot be assumed equal to ϕ, and the customary formulas cannot be used for finding the thrust on $A2$. The Rankine method is alone admissible, which consists in combining the thrust, $E = Pg$, acting parallel to the surface, with the weight of earth, $A2O = gg_2$, to find the true thrust, Pg_2, on the wall, $A\,2$. This acts at $\frac{1}{3}\,A\,2$ above A.

The plane of rupture, $A1$, is called the limiting plane. When the inner face of the wall, or retaining board, extends from A below it, the Rankine method just given must be used. If, however, the inner face of the wall or board extends from A above $A1$, then the usual (Cain) formulas apply.

For $\phi = 33° \ 41'$, the values of β and γ are as given in Table 1.

In Fig. 14, $i = 0°$ and $\alpha = 18° \ 26'$; the inner face of the wall lies above the limiting plane, as $18° \ 26' < 28° \ 10'$, and the Cain method is correctly given. In Fig. 15, however, the Cain and Rankine methods agree, and the sections should be identical, because, for $i = \phi$, $\beta = 0$,

* Formulas are derived in E. P., p. 102, for quickly computing these angles.

TABLE 1.

Mr. Cain.

i	β	γ
0	28° 10′	28° 10′
5°	26° 09′	30° 10′
10°	24° 03′	32° 16′
15°	21° 46′	34° 33′
20°	19° 08′	37° 11′
25°	15° 51′	40° 28′
30°	10° 59′	45° 20′
33° 41′	0°	56° 19′

and the limiting plane is vertical. The inner face of the wall lies below the limiting plane, and the Rankine method alone applies.

Similarly, the solution for Fig. 23 should be as indicated on Fig. 19, so that the remarks of the author, on pages 904-05,* relative to Fig. 23, do not apply to the writer's section, which is identical with Fig. 19.

To summarize: The corrections just given refer only to Figs. 15 and 23, where the methods of Cain and Rankine are identical; so that, in Fig. 15, the Cain section should coincide with the Rankine section, and Fig. 23 should be replaced by Fig. 19.

The author has brought out the interesting fact that the Rankine section of Fig. 11, where the earth surface is horizontal, is actually larger than that of Fig. 12, where the earth surface is at the angle of repose. For very many years, the writer has pointed out the inaccuracy of the Rankine method when applied to retaining walls with vertical backs, the earth being level at top (see E. P., pages 18, 52, 277), and hopes that engineers will note the additional fact deduced by Mr. Cornish, showing the inconsistency of the Rankine method.

The author has reached certain conclusions, in comparing Figs. 2 to 8 with the corresponding set, Figs. 9 to 15, from which the writer is constrained to differ, simply because cohesion is included in the designs, Figs. 2 to 8, but is omitted in computing the sections, Figs. 9 to 15. The variation of p for the first set then offers no criterion for judging of what its variation should be for the second set.

The experimental values of K_1, of Leygue, were found by the use of rotating boards backed by sand, the boards being 0.656 ft. (say, 8 in.) in height. The writer found that, on account of the very small height, the influence of cohesion was very marked, though only the very small value of cohesion of about 1 lb. per sq. ft., was exerted. Further, it was found, as exhibited in Table 3,† that the theoretical values of K_1, for a cohesion of about 1 lb. per sq. ft., agreed very well with the experimental values; so that sections of retaining walls, based on the experimental values of K_1, should agree very closely with the sections

Proceedings, Am. Soc. C. E., for August, 1916.

† "Experiments on Retaining Walls", etc., by the writer, *Transactions*, Am. Soc. C. E., Vol. LXXII (1911), p. 421.

Mr. Cain. found by theory for earth endowed with friction and a cohesion of 1 lb. per sq. ft., for walls 8 in. in height.

For walls 10 ft. high, a larger cohesion coefficient is required than 1 lb. per sq. ft., in order to give the experimental values of K_1 pertaining to the 8-in. walls, which the author has used. By using the construction, Fig. 11, of the paper just cited, it will be found, for earth weighing 100 lb. per cu. ft., level at top and deposited behind a vertical board, that the experimental value, $K_1 = 0.090$, corresponds to about 20 lb. per sq. ft. cohesion.

Figs. 2 to 8 can then be conceived to be theoretical designs for walls 10 ft. high, backed by earth weighing 100 lb. per cu. ft., with a cohesion of 20 lb. per sq. ft., and an angle of friction, $\phi = 33° 41'$, the masonry weighing 140 lb. per cu. ft., the theoretical and experimental values of K_1 being nearly the same. Now, the theoretical sections, Figs. 9 to 15 (Cain)—Fig. 15 being corrected as above—correspond to the same earth, but without cohesion. By reference to the paper cited,* it is seen, for the experimental walls examined, of sufficient height for cohesion to be negligible, that the experimental and theoretical values (Cain) of K_1 were practically identical; so that Figs. 9 to 15 can be regarded as walls designed for experimental values of K_1 for earth without cohesion.

Thus, Figs. 2 to 8, as well as Figs. 9 to 15 (Cain) can be regarded as sections designed for experimental values of K_1, the backing, in the first set, being of coherent earth, and in the second set, of non-coherent earth. If this is true, then both sets of sections are correct, and the author is unwarranted in his assumption that the variation of p in the first set offers any criterion for judging of what the variation should be for the second set. If these sections are regarded as experimental ones, as seems highly probable from the reasoning above, then the shortcomings of the Rankine sections, Figs. 11 and 12, are made evident by the comparison.

In the sections, Figs. 9 and 10 (Cain), the earth thrust has been assumed to make the angle, ϕ, with the normal to the wall. This assumption is nearly true where α is small (say, $\alpha < 10°$), but the investigations of Résal† lead to a definite formula for this obliquity, which the writer has adopted (E. P., p. 97), and which leads to a somewhat smaller value than ϕ, for the obliquity, for $\alpha = 18° 26'$. The sections, Figs. 9 and 10 (Cain), would thus be larger and would probably approach the Ketchum-Rankine sections. Experiments on model walls, from 6 to 10 ft. high, backed by clean sand, so that the influence of cohesion is negligible, are sadly needed, in order to check, or perhaps modify, theory, particularly with respect to leaning walls. In fact, it is known from experiment, that the surface of rupture is curved and

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* *Transactions*, Am. Soc. C. E., Vol. LXXII, pp. 407–413, 426.

† "Poussée des Terres", Vol. 1.

not plane, so that the theory of earth pressure against retaining walls, which assumes a plane surface of rupture, is admittedly approximate, and experiments on large models will almost certainly modify its indications.* Since there is no approximation introduced in the Rankine formula for the thrust on a vertical plane in an unlimited mass of earth, its results should agree with experiment and one would naturally expect the results pertaining to Fig. 15 (Rankine) to be verified by experiment. Mr. Cain.

Two noted authors, Boussinesq and Résal, have endeavored to complete the Rankine theory by considering the modifications necessary for those cases where the full friction of earth on wall is exerted. For such cases, both authors regard the earth thrust on the wall as making the angle, ϕ, with the normal to the wall. The case where $\phi' < \phi$ is not considered by either. Both theories are very intricate, but the results are probably more correct than those pertaining to the ordinary sliding wedge hypothesis used by the writer. The numerical values of K in Table 2 may prove interesting.†

TABLE 2.—VALUES OF K.

Earth Surface Horizontal.

α (1)	ϕ (2)	λ (3)	Boussinesq. K (4)	Résal. K (5)	Cain. K (6)
+ 20°	35° 00′	+ 18° 25′	....	0.071	0.064
+ 10°	"	+ 31° 49′	....	0.096	0.089
0°	33° 41′	+ 33° 41′	0.142	0.137	0.130
− 5°	"	"	0.159	0.156	0.152
− 10°	"	"	0.180	0.178	0.174
− 15°	"	"	0.206	0.203	0.203
− 20°	"	"	0.236	0.235	0.234
− 25°	"	"	0.274	0.273	0.272

In Table 2, α is the angle made by the inner face of the wall with the vertical; + referring to walls leaning toward the earth, and — referring to battered walls, as in Fig. 1. The angle of friction $= \phi$, the weight of earth $= w$, in pounds per cubic foot, and the thrust on the wall of height, h, is, $E = K\ wh^2$. Its component, normal to the wall, is $E_1 = K_1\ wh^2$. The thrust, E, makes the angle, λ, with and above the normal to the wall; hence $E_1 = E \cos. \lambda$ and $K_1 = K \cos. \lambda$.

* The modification will doubtless be more pronounced for leaning walls than for vertical or battered ones; because, when the wall leans toward the earth filling, the wedge of rupture is much smaller than for the battered walls; hence, any error due to assuming a plane surface of rupture in place of the true, curved one, should be more pronounced for the leaning walls, since, for them, the percentage of error made in the assumed wedge of rupture is greater for the leaning than for the battered walls. Further, the direction of the thrust on a leaning wall, derived from Résal's assumptions, needs experimental verification.

† The numbers in Columns (4) and (5) were made out partly by interpolation from tables, with some computation. For the Boussinesq theory, see tables by Flamant in *Annales des Ponts et Chaussées*, April, 1885. Résal's tables are given in his "Poussée des Terres".

Mr. Cain. The differences in the values of K given in Column 6 and in Columns 4 and 5 are greatest for the leaning walls and for a vertical wall. From values not given here, it can be seen that as the surface slope increases, the differences diminish; so that, for the earth surface at the angle of repose, for α negative, the coefficients, K, are the same by either of the three methods. Résal, alone, treats the case where α is positive.

The results of neither Boussinesq nor Résal are absolutely exact, their theories leading to differential equations that are not integrable. Boussinesq finds two limits to the thrust, and adds $\frac{9}{22}$ of their difference to the smaller to get the most probable value of the thrust. Résal assumes, as the basis of his analysis, that the stresses along any plane in a mass of earth are parallel and increase uniformly from the surface downward. This assumption, although true for the Rankine indefinite mass, may not be true for the earth near a retaining wall. Both authors, by independent methods, reach the conclusions above relative to the "limiting plane", Fig. 25, the method of the writer, however, being much the simplest.

It will be observed, from Table 2, that the corresponding values of K do not differ very materially, so that, with a proper factor of safety, walls designed by either method would not differ in section very materially. For the design of trapezoidal walls, the writer prefers the factor of safety method, exactly as outlined in his paper* previously quoted. In this, the normal component of the thrust is alone multiplied by the factor of safety—the object being to allow, somewhat empirically, for vibration and the lubrication of the back of the wall by water from heavy rains, which may be styled the "time effect". Lubrication might be allowed for by assuming a small value for ϕ' (where the formulas involving ϕ' apply), but vibration, due to heavy trains passing at high speed, defies analysis.

The theory of earth pressure against retaining walls is a most difficult one, and eminent mathematicians have exerted their best efforts to effect an exact solution without success, though close approximate solutions have been attained—notably by Résal and Boussinesq. Therefore, any light that can be thrown on the subject is welcome, and the author's comparative sections of triangular walls are very interesting. The subject has taken on increasing interest since a Special Committee of the Society has been appointed to investigate the matter experimentally, and it is hoped that its labors may be fruitful in results.

The great difficulties in reaching correct experimental results, with the many sources of error, are now better realized than ever before, which leads one to hope that results of value may be forthcoming in the near future.

As supplementing the graphical treatment of coherent earth, as given in the writer's paper last cited, a very brief analytical solution

* *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 433.

will be given of the case of active thrust of earth with a plane upper surface, which makes the angle, i, with the horizontal. The earth, of indefinite extent, will be supposed to be subjected to no external force but its own weight, so that, by a theorem due to Rankine, the pressure on a vertical plane in its interior acts parallel to the surface. Mr. Cain.

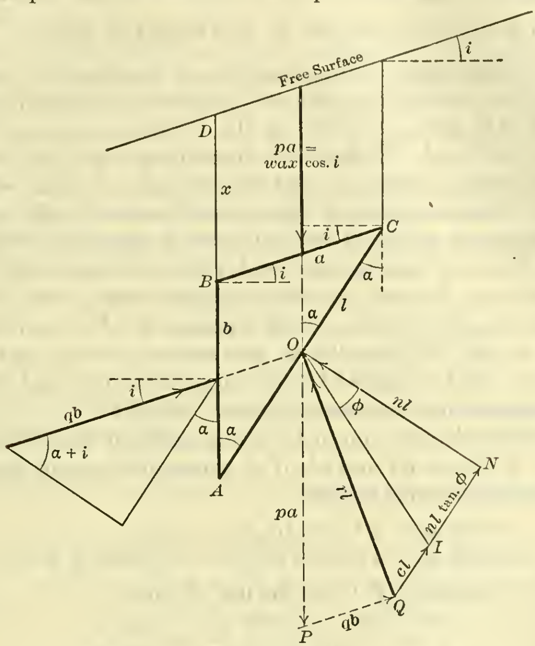

FIG. 26.

In Fig. 26, ABC represents an infinitesimal wedge of rupture, at a vertical depth, $x = BD$, in feet, below the free surface, the wedge having a length of unity perpendicular to the plane of the paper. The lower face, AC, is supposed to make an angle, α, with the vertical, AD. The angle, α, is always acute and cannot exceed $90° - i$, when AC is parallel to the free surface. The upper face, BC, of the wedge is parallel to the free surface and AB is vertical. For brevity, let the length $AB = b$, $BC = a$, and $AC = l$. As these lengths will be supposed to be indefinitely small, the unit pressures on each face, AB, BC, AC, can be regarded as uniform.

Let w = weight of earth, in pounds per cubic foot;
ϕ = angle of friction;
c = cohesion, in pounds per square foot;
p = vertical unit pressure on BC;
q = unit pressure on AB, acting parallel to the free surface;
n = normal component of unit pressure, r, on AC.

Mr. Cain. It is understood that ϕ and c have been determined by experiment,* and it must be carefully noted that, except when $c = 0$, ϕ is not the angle of repose.

The vertical prism of earth vertically over BC has a horizontal section with an area of a cos. i and a volume xa cos. i, so that vertical pressure on BC is, $pa = wax$ cos. i. The weight of ABC is $\frac{1}{2}$ wab cos. i, which is a second-order infinitesimal (as it involves ab); hence it can be neglected in comparison with the first-order infinitesimal, pa. The pressure on AB, acting parallel to the surface is qb, and the normal reaction on AC is nl. If motion is impending down AC, it is resisted by the full friction, nl tan. ϕ, and the cohesion, cl, both acting up the plane, AC. The resultant of the normal reaction (nl) and the tangential component ($cl + nl$ tan. ϕ) is rl, as shown on Fig. 26, where $ON = nl$, $NL = nl$ tan. ϕ, $LQ = cl$, $QO = rl$, and $NOL = \phi$. The three forces, pa, qb, and rl, acting on the wedge, ABC, must be in equilibrium; hence OPQ is a closed triangle, if OP is laid off vertically (to scale) $= pa$, PQ, parallel to the surface, $= qb$, and $QO = rl$. Otherwise, if QO is replaced by its components, QN and NO, equilibrium is indicated by the closed polygon, $OPQNO$.

For equilibrium, the sum of the components of pa, qb, and the components ($cl + nl$ tan. ϕ) and nl, of rl, perpendicular and parallel to AC must be separately equal to zero.

$$p\,a \sin.\,\alpha + q\,b \cos.\,(\alpha + i) = n\,l \qquad \text{(1)}$$

$$p\,a \cos.\,\alpha - q\,b \sin.\,(\alpha + i) = n\,l \tan.\,\phi + c\,l \qquad \text{(2)}$$

From the triangle, $A\ B\ C$, by the law of sines,

$$\frac{b}{a} = \frac{\cos.\,(\alpha + i)}{\sin.\,\alpha},\ \frac{l}{a} = \frac{\cos.\,i}{\sin.\,\alpha}.$$

On dividing Equations (1) and (2) by a, and substituting the values of $\frac{b}{a}$, $\frac{l}{a}$, and clearing of fractions,

$$p \sin.^2 \alpha + q \cos.^2 (\alpha + i) = n \cos.\,i,$$

$$p \cos.\,\alpha \cos.\,\phi \sin.\,\alpha - q \sin.\,(\alpha + i) \cos.\,\phi \cos.\,(\alpha + i)$$
$$= n \sin.\,\phi \cos.\,i + c \cos.\,\phi \cos.\,i.$$

Substitute in the last equation the value of n cos. i from the preceding equation, transpose, and factor,

$$p \sin.\,\alpha\,[\cos.\,\phi \cos.\,\alpha - \sin.\,\phi \sin.\,\alpha]$$
$$- q \cos.\,(\alpha + i)\,[\sin.\,(\alpha + i) \cos.\,\phi + \cos.\,(\alpha + i) \sin.\,\phi]$$
$$= c \cos.\,\phi \cos.\,i;$$

or,

$$p \sin.\,\alpha \cos.\,(\alpha + \phi) - q \cos.\,(\alpha + i) \sin.\,(\alpha + i + \phi)$$
$$= c \cos.\,\phi \cos.\,i \qquad \text{(3)}$$

* After the methods outlined by the writer in "Cohesion in Earth", or methods based on the same principles. *Transactions*, Am. Soc. C. E., Vol. LXXX (1916), p. 1315.

The true active thrust corresponds to that value of α that makes $q\,b$ or q a maximum.* For a maximum q, $\frac{d\,q}{d\,\alpha} = 0$; hence differentiating Equation (3) with respect to α, and putting $\frac{d\,q}{d\,\alpha} = 0$ (which cancels one term), we have, Mr. Cain.

$$p\,[\cos.\ \alpha \cos.\ (\alpha + \phi) - \sin.\ \alpha \sin.\ (\alpha + \phi)]$$

$$- q\,[\cos.\ (\alpha + i) \cos.\ (\alpha + i + \phi) - \sin.\ (\alpha + i) \sin.\ (\alpha + i + \phi)] = 0;$$

whence,

$$p \cos.\ (2\ \alpha + \phi) - q \cos.\ (2\ \alpha + 2\ i + \phi) = 0 \ldots\ldots (4)$$

Equations (3) and (4) give the solution, which thus corresponds to the least value of q for which equilibrium is possible. This value of q is the unit conjugate thrust at B, at depth x, corresponding to the limit, as b tends indefinitely toward zero.

When $q = 0$, from Equation (4), $\cos.\ (2\ \alpha + \phi) = 0$; therefore

$$2\ \alpha + \phi = 90°, \text{ or, } \alpha = 45° - \frac{\phi}{2}.$$

On substituting this value of α in Equation (3) and putting $q = 0$, $p = w\,x' \cos.\ i$, we obtain,

$$w\,x' \cos.\ i \sin.\left(45° - \frac{\phi}{2}\right) \cos.\left(45° + \frac{\phi}{2}\right) = c \sin.\ (90° - \phi) \cos.\ i$$

$$= 2\ c \sin.\left(45° - \frac{\phi}{2}\right) \cos.\left(45° - \frac{\phi}{2}\right) \cos.\ i.$$

Therefore

$$x' = \frac{2\ c}{w} \tan.\left(45° + \frac{\phi}{2}\right) \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

where x' = the vertical depth from the surface to where the conjugate thrust, $q = 0$.

In Fig. 26, the case where $q = 0$, would require $P\ Q = 0$, so that $Q\ O$, the reaction of the corresponding plane of rupture, $A\ C$, would be vertical. For $x < x'$, q remains zero and $p\,a = O\ P$ = the weight of the prism of earth vertically over $B\ C$, is entirely sustained by $n\ l$ (corresponding), combined with only a part of $(c\ l + n\ l \tan.\ \phi)$, so that the reaction, $r\ l = Q\ O$, remains vertical for any value of x from zero to x' and there is no thrust, q, on a vertical plane for the depth, x'. In fact, it can be shown generally from Equations (3) and (4) that when $0 < x < x'$, q will come out negative, or Q will lie to the left of P, indicating that a pull, $q\ b$, on $A\ B$ is necessary for

* In Fig. 26, let PQ' represent a less thrust than the maximum, PQ, where Q' (not shown) is on PQ to the left of Q. Draw a line from Q' parallel to QN to the intersection N' with ON and lay off on it $Q'L' = QI = cl$. The new closed polygon of forces, corresponding to $OPQNO$, is $OPQ'L'N'O$. Now, however, $N'OL'$ is greater than ϕ; but ϕ being a constant, it is inconsistent with equilibrium that the angle of friction required by the new construction, $N'OL'$ should exceed ϕ; hence a less thrust than the maximum, $qb = PQ$, is inconsistent with equilibrium.

Mr. Cain. equilibrium, if the full friction and cohesion on $A\ C$ is exerted. Therefore, equilibrium is possible when $q = 0$, and only a part of $(c\ l + n\ l \tan. \phi)$ is exerted. It follows that, for the unlimited mass of earth, subjected to no force but its own weight, there is no stress on a vertical plane in the mass, for the depth, $x = 0$ to $x = x'$.

When, from any cause, the earth tends to move away to the left of $B\ D$, a pull will be exerted on $B\ D$ for a depth, x', and its value, at depth, $x < x'$, can be found from Equations (3) and (4). This implies that the earth is capable of exerting the tension required. As clayey earths, after heavy rains, often form vertical cracks during the subsequent drying out and contraction, it seems unwise to depend on this tension, either in the case of stable slopes or retaining walls. The tension may be exerted for some time, but eventually it may and doubtless will be destroyed. In the writer's paper,* Fig. 11, page 416, refers to the case where tension is supposed to be exerted over the depth, x'; and Fig. 25, page 461, to the case where no tension is supposed to be exerted from the surface to the depth, x', given by Equation (5).

The method of solution of Equations (3) and (4) will now be indicated,† using a numerical illustration. Let $i = 30° = \phi$, $c = 100$ lb. per sq. ft., $w = 100$ lb. per cu. ft. From Equation (5), find $x' = \frac{2\ c}{w} \tan. \left(45° + \frac{\phi}{2}\right) = 2 \tan. 60° = 3.46$ ft. At this depth, as proved above, $\alpha = 45° - \frac{\phi}{2} = 30°$. Next, eliminate q between Equations (3) and (4), and substitute $w\ x \cos.\ i$ for p. The equation can now be solved for x, and on substituting increasing values of α, starting with $\alpha = 30°$, the values of x given in Table 3 can be found.

TABLE 3.—VALUES OF x.

α	x, in feet.	q, in pounds per square foot.
30°	3.46	0
35°	5.26	84
40°	8.42	253
45°	15.00	646
50°	32.70	1 847
55°	124.00	8 738

The values of α give the angles made by the plane of rupture, AC, Fig. 26, for the successive vertical depths, x, from the surface, so that the curved surface of rupture, AS, Fig. 27, can be approximately

* "Experiments on Retaining Walls", *Transactions*, Am. Soc. C. E., Vol. LXXII.

† The method is very long and tedious, and not adapted to practice; hence the writer was led, in his book on "Earth Pressures", to utilize Mohr's "circular diagram of stress", not only to develop the theory of coherent earth, but also to reach numerical results with facility. See Chapter V of that treatise on the complete theory of coherent earth.

Mr. Cain.

drawn. It approaches indefinitely parallelism to the surface at great depths for $i = \phi$, assumed. The region, of depth x', sustains no conjugate stress. To find the values of the conjugate stress, q, at the depths, x, given above, substitute in Equation (4) the values of α corresponding and replace p by wx cos. i. The values of q are quickly computed for the corresponding values of α and x given above. The conjugate stress, q, acts parallel to the surface, but it was laid off horizontally in the figure. The curve corresponding is slightly concave upward. When $i = 0$, the surface of rupture is plane; for $i > 0$, it is curved and concave upward, and the curvature increases with i. Thus, α is found to increase with the depth, and may attain the limiting value, $\alpha = 90° - i$, when AC, Fig. 26, is parallel to the surface.

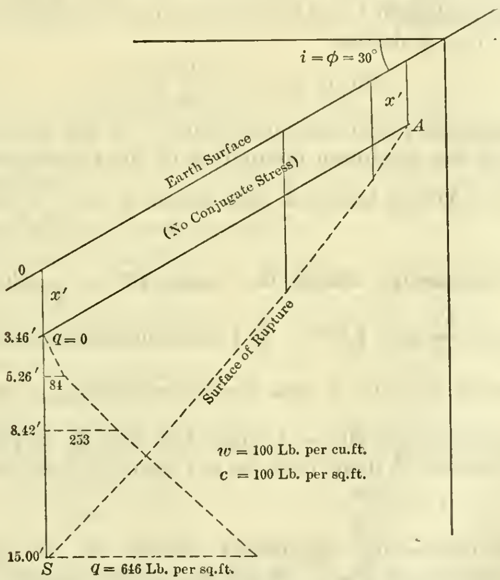

FIG. 27.

On substituting $\alpha = 90° - i$ in Equations (3) and (4), we at once find,

$$\left.\begin{aligned} p &= \frac{c \cos. \phi}{\sin. (i - \phi)}; \\ q &= \frac{c \cos. (2\,i - \phi)}{\sin. (i - \phi)} \end{aligned}\right\} \qquad (6)$$

Since p is always finite and positive, the case cannot occur when $i < \phi$ or $i = \phi$, but it does occur when $i > \phi$ at a certain depth, which call x_0. Thus, substituting $p = wx_0$ cos. i, in the first of Equations

Mr. Cain (6), we find the limiting depth at which the surface of rupture is parallel to the surface,

$$x_0 = \frac{c \cos. \phi}{w \cos. i \sin. (i - \phi)} \dots\dots\dots\dots\dots\dots (7)$$

There is no equilibrium for a greater depth, since α cannot increase farther, no wedge of rupture, *ABC*, Fig. 26, being formed. Thus slipping is impending at $x = x_0$, and would occur for $x > x_0$, unless the earth is confined by walls, natural or otherwise, the resistance of which thus introduces external forces not contemplated in the theory of the unlimited mass, subjected to no external force but its own weight.

If, in Fig. 26, we drop a perpendicular from B on the "free surface", and call its length h, we have $h = x_0 \cos. i$; whence, substituting in Equation (7), we derive,

$$\sin. (i - \phi) = \frac{c \cos. \phi}{w\, h} \dots\dots\dots\dots\dots\dots (8)$$

From this equation, for an assumed value of h, the value of i can be found. This is the maximum inclination of the surface corresponding to the given h. After i has been thus found, $x_0 = \frac{h}{\cos. i}$ can be computed.

When i, increasing, attains the value, $45° + \frac{\phi}{2}$, the value of x_0 reduces to, $x_0 = \frac{2\, c}{w} \tan. \left(45° + \frac{\phi}{2}\right) = x'$, by Equation (5). At this depth, x' (where $q = 0$), it was found above that, $\alpha = 45° - \frac{\phi}{2}$, as should be, since $\alpha = 90° - i$ when *AC*, Fig. 26, is parallel to the surface. It follows, if there is to be any active thrust, that we must always have, $i < 45° + \frac{\phi}{2}$.

The most interesting conclusions relative to the general case, $i > 0$, have now been given. When the earth surface slopes downward to the right from *D*, Fig. 26, the conjugate thrust still acting parallel to the surface, it can be shown that Equations (3) and (4) hold, on simply replacing i by $(-i)$.

It is not the intention to enter into passive thrust or resistance, but it may be stated that the solution can be effected along lines similar to those used in the case of active thrust.*

For active thrust, the most important case is that for which $i = 0$, or the free surface horizontal. From Equation (4) we obtain, at once, $\cos. (2\, \alpha + \phi) = 0$; whence, $\alpha = 45° - \frac{\phi}{2}$, for any x.

* In the writer's "Earth Pressures", the case of passive thrust is fully discussed by aid of Mohr's circular diagram of stress.

It follows that the surface of rupture is plane, and that it bisects the angle between the vertical and the line making the angle, ϕ, with the horizontal. Mr. Cain.

On substituting, $\alpha = 45° - \frac{\phi}{2}$, in Equation (3), putting $w\,x$ for p, solving for q, and reducing,

$$q = \tan.\left(45° - \frac{\phi}{2}\right)\left[w\,x\,\tan.\left(45° - \frac{\phi}{2}\right) - 2\,c\right] \ldots\ldots (9)$$

This equation can be written in the form,

$$q = w\,\tan.^2\left(45° - \frac{\phi}{2}\right)\left[x - \frac{2\,c}{w}\tan.\left(45° + \frac{\phi}{2}\right)\right].$$

Therefore,

$$q = w\,\tan.^2\left(45° - \frac{\phi}{2}\right)\left[x - x'\right] \ldots\ldots\ldots\ldots (10)$$

where, Equation (5), $x' = \frac{2\,c}{w}\tan.\left(45° + \frac{\phi}{2}\right)$, is the depth at which $q = 0$, as found above for any i.

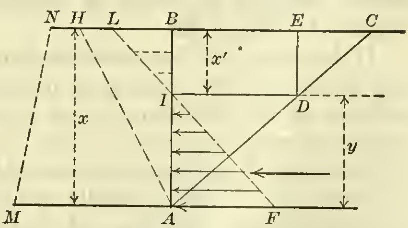

FIG. 28.

The results are as indicated in Fig. 28, where BC is the horigontal free surface, and at depth, x, q (to scale) is represented by FA. The plane of rupture is AD, and $DE = IB = x'$; so that, for the unlimited mass of earth, as shown above, there is no horizontal stress on IB or DE, the weight of EDC being supported by the vertical reaction of DC. The conjugate horizontal stress on the vertical plane, AB, is thus null on the portion, IB, and increases uniformly from I to A, so that its resultant, $\frac{1}{2}\,w\,y^2 \tan.^2\left(45° - \frac{\phi}{2}\right)$, acts at $\frac{1}{3}\,A\,I = \frac{1}{3}\,y$ above A, where $y = x - x'$.

The case is different for a limited mass of earth supported by a retaining wall, $AHNM$, which moves over slightly to the left. First, suppose AH to lie below the "limiting plane", making the angle, $45° - \frac{\phi}{2}$, with the vertical. In this case, if the earth is capable of exerting tension in the layer, $IDCB$, the stress on IB will be tensile, increasing uniformly from I to B, the unit tension at the depth, $x < x'$, being given by Equations (9) or (10), corresponding to the

Mr. Cain. minus sign of q. At $x = 0$, the numerical value of this tension is, $q_0 = 2\,c\,\tan.\left(45° - \frac{\phi}{2}\right) = L\,B$, say, and the total tensile stress on $I\,B = \frac{1}{2}\,x'\,q_0 = \frac{2\,c^2}{w}$. This stress, $\frac{2\,c^2}{w}$, acts horizontally to the right at a point on $A\,B$, $\frac{x'}{3}$ below B.

The total stress on AB is thus the difference between the resultant stresses on AI and IB, and the position of the resultant of the two can be found by taking moments. This total stress on AB can be put in another form by integrating qdx between the limits $x = AB$ and zero. Using Equation (9), the total stress is found to be,

$$\tan.\left(45° - \frac{\phi}{2}\right)\left[\frac{w\,x^2}{2}\tan.\left(45° - \frac{\phi}{2}\right) - 2\,c\,x\right].$$

The tensile stress in the upper layer, of depth, x', is transmitted to DE, where its effect is to cause impending motion downward of the wedge, DCE, so that the whole of the friction and cohesion possible, is exerted on AC. In fact, if we regard ABC as the wedge of rupture, it can be independently proved that the total horizontal thrust is exactly that given by the last equation. In this case, the total thrust on the wall can be found by combining the thrust on AB with the weight of earth, AHB.

If, however, AH lies above the limiting plane, the graphical method of Fig. 11* can be applied, in order to find the stress on AH. The position of this resultant stress is uncertain. There are no tensile stresses exerted by the wall on the earth, so that the state of stress on AB is changed, particularly when AH is vertical, in which case, the stress on $AH = AB$, is wholly compressive, though exerted only over a lower portion. The state of stress in the mass, ABC, is complex, involving tension over DE, but only compression over a part of AH. As an approximation, the position of the resultant thrust on AB, for $x > x'$, can be assumed to be the same as in the first case, where AH was supposed to lie below the limiting plane, and the thrust on AH can be taken at the same or a slightly greater height.

The case will not be entered into further, because, for purposes of design of walls, it seems unwise to count on any tension in the layer, BD, as a permanent feature. Then, if AH lies below the limiting plane, the thrust on AI,

$$\frac{1}{2}\,w\,y^2\tan.^2\left(45° - \frac{\phi}{2}\right),$$

acting $\frac{y}{3}$ above A, is combined with the weight of earth, BAH, to find the resultant thrust on the wall.

* "Experiments on Retaining Walls", *Transactions*, Am. Soc. C. E., Vol. LXXII, p. 416.

If AH lies at or slightly above the limiting plane, the same method will suffice; but, as AH approaches the vertical, this method will lead to exaggerated dimensions of the wall, and resort can be had to the graphical method of Fig. 25* in order to find the thrust on the wall. Mr. Cain.

A word may be appropriately added here as to Résal's monumental work, "Poussée des Terres, II, Théorie des Terres Cohérentes" (1910), which is the first complete treatise on coherent earth to appear. The solutions of all the cases, for both active and passive thrust, are included in one general formula. In the treatment of the one case of active thrust above, the writer used a different independent variable from Résal, so that the general Equations, (3) and (4), are not the same as the corresponding ones of Résal, but are equivalent, for the case considered, and lead to the same conclusions. Résal's treatment of retaining walls, backed by coherent earth, is cumbersome, and the writer prefers a more exact method, which is in reality shorter and more convincing. This criticism, however, does not apply to Résal's general analysis of earth pressure, which will doubtless always prove as inspiring to subsequent investigators as it has to the writer.

G. M. Braune,† Assoc. M. Am. Soc. C. E. (by letter).‡—The writer is in sympathy with Mr. Cornish when, in closing his paper, he says: Mr. Braune.

"The writer has never been able to find or think of any good reason for assuming that the slope of surcharge should govern the slope of the resultant earth thrust for great depths."

There are two general original theories or principles for determining the earth pressure against retaining walls—namely, Coulomb's and Rankine's.

Coulomb's theory is preferable, for the main reason that the selection of the direction of the earth pressure may be assumed to fit each individual case. If there is no friction between the filling and the wall, the earth pressure would act normally to the back of the wall; if the angle of friction between wall and filling is equal to ϕ', then the earth pressure would be inclined to the normal under an angle that would approach the value of ϕ'. Whether the earth pressure is chosen normal to the back of the wall or inclined does not make very much difference in the magnitude, but it does affect considerably the overturning moment about the toe of the wall, therefore a judicious selection of the direction is an important feature in the design of walls.

Dr. Müller-Breslau has made some experiments at the Charlottenburg Laboratory on earth pressures, and as the writer believes that the results of these experiments are not generally known, certain parts of them will be given.

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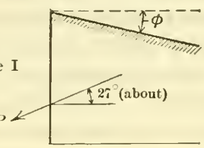
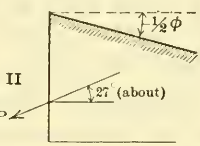
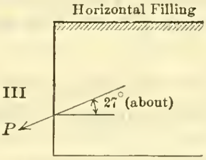
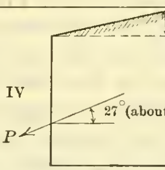
* *Transactions*, Am. Soc. C. E., Vol. LXXII, pp. 461, 466.

† Cincinnati, Ohio.

‡ Received by the Secretary, October 14th, 1916.

Mr. Braune.

TABLE 4.

	Magnitude of P. (1)	Direction of P to the normal. (2)	Point of application. (3)	Computed P, after Coulomb, using direction as determined from experiments. (4)
Case I 	91 kg.	About 27°	0.31 h	89 kg. (88.6 kg.)*
Case II 	113 kg.	About 27°	0.33 h	98 kg. (103 kg.)*
Case III Horizontal Filling 	134 kg.	About 27°	0.36 h	124 kg. (122 kg.)*
Case IV 	195 kg.	About 27°	0.375 h	183 kg. (187.5 kg.)*

* The figures in parentheses in Column (4) give the value of P as computed by the writer for an angle of direction of 27°0′.

In Case 4, evidently a clerical error was made in stating that the angle of surcharge equaled $\frac{1}{2}\,\phi = 16°$, and giving a computed value of P as 183 kg. for this angle. The value, 187.5 kg., was computed by the writer, using a surcharge angle equal to $\frac{3}{4}\,\phi = 24°$.

In describing these experiments, the height of wall is given as 744 mm.; the filling used was ordinary sand, weighing 1 600 kg. per cu. m. The angle of friction between the back of the wall and the sand was found to be 31° 8′, and the angle of repose 32 degrees. The average results secured on the vertical backs are shown in Table 4. The magnitude, direction, and point of application were determined

for different slopes of filling behind the wall. The values, as determined from Coulomb's formula, using the angle of direction as determined from the experiments (27°), are given as a comparison with the experimental values. Mr. Braune.

It will be noticed that the inclination of the filling back of the wall had practically no influence on the direction of the earth pressure, contrary to Rankine's theory. In connection with these experiments, it might be stated that no allowance was made for the frictional resistance between the material and the sides of the box, which would make some changes in the magnitude of the earth pressures, but probably would not have much effect on the direction.

In view of these experiments, Dr. Müller-Breslau recommends that the angle between the direction of earth pressure and the normal should not exceed three-quarters of the angle of repose, even with good drainage and a rough surface on the back of the wall, and provides that the resultant shall cut the base at one-quarter back from the toe.

The nature of the foundation, of course, would control the point of application of the resultant. For unyielding foundations, the resultant could safely fall outside of the middle third, provided, of course, the material is not stressed beyond a safe working limit.

It is the writer's intention to undertake some earth pressure experiments at the University of Cincinnati, commencing this fall (1916), and an endeavor will be made to eliminate the effect of frictional resistance resulting from the pressure on the side-walls.

F. N. Menefee,* Assoc. M. Am. Soc. C. E. (by letter).†—The writer has watched, with a great deal of interest and profit, the results of Mr. Cain's plea for more light on the subject of cohesion in earth, bringing out facts bearing directly on the behavior of soil itself, as well as more information on the closely related subject of retaining walls. The following remarks are a result of the writer's attempt to choose a formula for the amount and direction of the earth pressure behind an 80-ft. retaining wall. Mr. Menefee.

It is generally conceded that Rankine's formulas give conservative results and that in most cases the modified formulas developed by other investigators are rational and well within the bounds of good mechanics. There is, however, one noticeable incongruity when the direction of the resultant thrust obtained by these formulas is compared with that obtained by simple mechanics. To illustrate this point the writer will refer to the author's diagrams and to the discussion by Messrs. Goodrich and Cain on the paper entitled "Cohesion in Earth: The Need for Comprehensive Experimentation to Determine the Coefficients of Cohesion."‡

* Jackson, Mich.

† Received by the Secretary, October 18th, 1916.

‡ *Transactions*, Am. Soc. C. E., Vol. LXXX, pp. 1315–1341.

Mr. Menefee.

Mr. Cornish mentions the confusing differences of direction of the resultant pressure as given by different formulas, whereas, with a given coefficient of friction between the earth in question and the material in the wall, it appears to the writer that there is only one possible maximum slope to the resultant, regardless of the assumptions made as to the angle of repose or the slope of the surcharge. The writer appreciates the correctness of the formulas considering the assumptions, and also the part which conjugate stresses play where there is a surcharge, but believes that if the coefficient of friction of the earth against the wall can be determined, sufficient data immediately become available for finding the slope of the resultant pressure. For instance, referring to Fig. 13, the resultant pressure is given a slope equal to that of the surcharge. The magnitude, by Leygue's formula, is 4 146 lb., which, with the slope given, makes the component, parallel to the back face of the wall, 2 308 lb. In the common friction formula the tangential force necessary to move an object, divided by the normal force, is the coefficient of friction. For the case chosen, then, 2 308 ÷ 4 160 = 0.555, or there must be a coefficient of friction of 0.555 in order to give the force of 2 308 lb. parallel to the back face of the wall. In designing retaining walls, however, do we know that such a coefficient exists, between the earth and the wall, or do we even investigate it? In choosing a formula for finding the resultant pressure, it seems to the writer that we approach the problem backward and reach a conclusion which may or may not be true, for, if the coefficient of friction is not as great as 0.555, no number of formulas, however well deduced, will make it so. Suppose, for instance, that it was determined by experiment that the coefficient of friction for the earth on the wall in question was 0.35; then the maximum possible tangential force on the back of the wall would be 1 455 lb., and the slope of the resultant could not be greater than 1 455 ÷ 4 160, or about 19° 16′. Before any greater force parallel to the back of the wall could be developed, slipping would result.

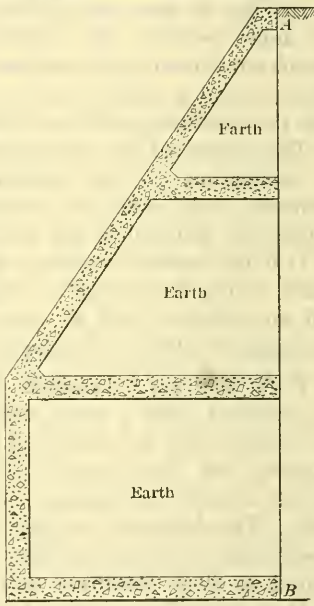


FIG. 29.

In designing some high counterforted walls of the general shape shown in section in Fig. 29, the writer found that the normal pressure

of the embankment came on the earth in the cells of the wall. In this case, both friction and cohesion would act, if called on, and cause a downward force parallel to the back of the wall; but that tangential force could never be more than friction and cohesion would develop, and for that reason the writer argues that, instead of attempting to get the slope of the resultant by formula, the coefficient of friction and cohesion of the earth in question should be determined, which, when multiplied by the normal force, will give the maximum tangential force that can be developed on the back of the wall. Mr. Menefee.

According to the tabular values in Figs. 1 and 2 in the discussion by Messrs. Goodrich and Cain, one-fourth is not an uncommon value for the coefficient. This means that any resultant force obtained by formulas in which the slope is greater than one-fourth is incorrect, in direction at least, for its component parallel to the back of the wall would be sufficient to cause rupture along the plane, *A B*.

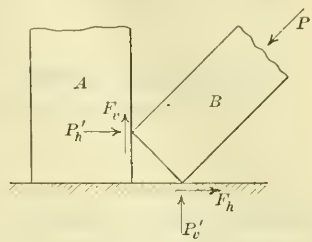


FIG. 30.

Further illustration might be made by resorting to the mechanics involved in Fig. 30. Suppose a block, *B*, is being pushed by a force, *P*, against another block, *A*, resting on the floor, as shown. The force, *P*, may be decomposed into a horizontal force, P_h, and a vertical force, P_v. Then

$$P_v = F_v + P'_v \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

and

$$P_h = F_h + P'_h \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$F_v = P_h \times$ (coefficient of friction + cohesion), and no more. If F_v is not sufficient to equalize P_v, then P'_v must increase until Equation (1) holds. As F_v depends on the normal force and the coefficient of friction and cohesion, and F_v is equal in magnitude and opposite in sense to the active vertical component of *P*, then the writer believes that the most direct method of obtaining the vertical component of *P* is by that outlined above.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

UNDERPINNING TRINITY VESTRY BUILDING FOR SUBWAY CONSTRUCTION

Discussion.*

By Messrs. Elias Cahn, T. Kennard Thomson, James F. Fouhy, Charles Rufus Harte, Joseph A. A. Connelly, J. S. Branne, and A. W. Buel.

Elias Cahn,† Assoc. M. Am. Soc. C. E. (by letter).‡—The writer has read this paper with great interest, particularly the part relating to the tests on concrete piles, and considers the Profession greatly indebted to the author for their publication. It is a pity, however, that these valuable tests were not extended to include the influence of other factors bearing on the supporting power of these piles and their settlement under load, no less important than those considered. Time is one of these factors, and should not be neglected in dealing with earth, because stresses travel so slowly through this medium. All the tests, particularly No. 5, give indications of this, but the time taken in any of them, about 1 hour, is very far from sufficient to develop this influence fully. The depth to which a pile is driven is also an important factor. Mr. Cahn.

The following, therefore, are suggested as additions to the author's conclusions:

(8) The settlement accompanying the development of a certain pressure will be greater, the longer the time taken to develop this pressure.

(9) A pile will settle under the action of a constant pressure at a rate and for a time depending on the pressure, the area of the base

* Discussion of the paper by H. de B. Parsons, M. Am. Soc. C. E., continued from October, 1916, *Proceedings*.

† New York City.

‡ Received by the Secretary, October 14th, 1916.

Mr. Cahn. of the pile, the kind of material which the pile penetrates, and the surcharge over the horizontal plane through the bottom of the pile.

The earth immediately under the pile, when subjected to the maximum pressure of the jack, as is clearly indicated by the rebound, is in a state of excessive compression, which undoubtedly decreases in all directions from this point. There will be a tendency to equalize this compression in time, thereby reducing that immediately under the pile, and either decreasing its resistance or causing further settlement.

The conditions under which equilibrium is finally obtained and the total settlement in time under a definite pressure or load, are the determinants of what the safe load should be, rather than the pressure it is possible to develop with the jack in a short time.

In Conclusion (5) no mention is made of the effect, on its supporting power, of the depth to which the pile is driven. This depth, for any given earth, determines the compression that the material under the pile will stand permanently, and therefore the load it will support.

The practice of considering the safe load as one-half the maximum pressure obtained with the jack, therefore, is not logical unless the depth of penetration and the kind of earth as well as the area of the base of the pile are considered in determining the pressure to be obtained with the jack. Aside from any difference in the skin friction, a pile driven 30 ft. into the earth would have a greater supporting power than if driven only 15 ft., though the same pressure is obtained with a jack in the manner described in the paper, simply because the earth at the lower level will stand permanently a greater degree of compression than at the upper level.

The author has done more than his share in conducting the tests recorded, and it is to be hoped that those who may have the opportunity in the future will continue where he has left off, clearing up this matter of the effect of time and of depth of penetration on the settlement of a pile under a constant pressure after the earth under it has been compressed by a far greater pressure.

Mr. Thomson. T. Kennard Thomson,* M. Am. Soc. C. E.—It is a pleasure to see a well-designed piece of work well carried out, and then well described; and the Society is once more indebted to Mr. Parsons.

Whenever the writer sees a "jack" under a building he thinks of the comments of an eminent lawyer who was wont to laugh at engineers for their careless use of the English language, for he claimed that they nearly always referred to the process of "jacking up the building"; whereas, they did not do anything of the sort, as the method was to put a jack between the base of a building and a post

* New York City.

or sill resting on the ground and then, by operating the jack, force the post or sill into the ground, keeping the building itself exactly where it was, instead of "jacking it up". Mr. Thomson.

The sentimental reasons against disturbing the church building and graveyard undoubtedly entered into the selection of this design. The contract price, as stated by the author, was $982 740 for 1 000 ft. Otherwise, it might have been cheaper to tear down the old building instead of underpinning it. However, the occupants of the building and countless thousands of pedestrians gained by the lack of disturbance of surface conditions.

It was fortunate in this case that two of the most dangerous elements, often encountered in underpinning operations, were absent—that is, water, and bad design or construction of the building to be underpinned.

The speaker recalls one building which caused him much worry, due to its very defective—to say the least—construction. It was some twelve stories high; the two lower floors were supported by cast-iron and steel columns of various shapes and the floors above were carried by brick walls. The first joint uncovered disclosed the fact that two 20-in. beams did not rest on the shelf brackets of the cast-iron columns, as there was at least a 2-in. space between the bottom of the I-beams and the top of the shelf, and although there had been provision for several bolts to connect the flange of the columns to the webs of the beams, only one bolt, for each beam, had been put in place—so all the support which the heavy 20-in. I-beams had was one ¾-in. bolt each. If a safe or any other heavy article had ever been moved over these beams, there would have undoubtedly been a bad collapse.

Needless to say, the disclosure of such an unsafe condition in the first joint uncovered caused much worry about the possible condition of the many joints in the building, which it was not possible to uncover for examination. However, the building, which rested on quicksand, at the surface of the ground-water, was safely underpinned by forcing cylindrical caissons to bed-rock from 60 to 70 ft. below the water surface, through New York quicksand.

The speaker has underpinned walls eighteen stories high, by putting cylindrical caissons down by the Breuchaud method, through 70 ft of water and quicksand, and then constructing a cellar for the new building 35 ft. under water.*

In underpinning a six-story building by jacking down 16-in. pipes until they were supposed to have reached hardpan (as a matter of fact they offered so much resistance to the jacks that the weight of the old building was really taken off the old foundations, as shown by horizontal cracks in the brickwork), it was found, after all the sand had

* A full description of this work was published in *Engineering News,* March 28th, 1901.

Mr. Thomson. been washed out of the cylinders and they had been filled with good concrete, which should have made the underpinning strong enough to carry very much heavier loads than those to which they were subjected (for the building was practically raised by jacking against the empty pipes, that is, before they had been filled with concrete) that the cylinders actually settled when the pneumatic caissons were being sunk near-by, thus loosening up the soil around the pipes and thereby destroying the friction. It would seem, therefore, that dependence cannot be placed on such pipes when the surrounding material is likely to be disturbed.

The author states that in the Trinity Vestry Building the friction of the material around the pipes was disregarded, and that the pipes were treated as short columns having all the load transmitted to the base, but these pipes were comparatively short. The length of such cylinders is often 30 ft. or more; they are too long to be considered as short columns, and offer very considerable resistance, due to the friction of the earth.

Owing to this lack of reliability, the speaker does not usually recommend underpinning with cylinders, unless they are large enough to permit a man to enter them to excavate the material and then fill them with concrete. A cylinder having an outside diameter of 30 in. is about the smallest that can be used for this purpose.

It pays to use an ample thickness of metal in the cylinders, for the speaker has seen them made so thin that it was impossible to see the bottom of the excavation from the top, owing to the warping of the pipes while being jacked down.

On removing some old buildings on Wall Street, New York City, which, about 14 years previously, had been underpinned by 14-in. pipes jacked down and filled with the best of concrete (paper bags having been used there also), except for the bottom 2 ft. of the cylinder, it was found that it had been impossible to pump out all the sand, and the concrete had probably set without thoroughly compressing the sand in the lower 2 ft. of the pipe.

This, of course, would allow the building to settle at least a few inches, if it ever happened that the friction of the soil against the pipe was insufficient to carry the load, as is often the case when the soil is disturbed.

In underpinning, as in other foundation work, no hard-and-fast rules can be laid down, as each building requires a treatment of its own.

The author refers to the rebound of the cylinders after the jacks were removed, and the method taken to prevent it. The usual method, however, is to use steel wedges, either between steel plates and beams, or between granite wedging blocks.

The speaker tested some open concrete caissons for a bridge in

New Jersey a few years ago, and measured the rebound. The cylinders were of reinforced concrete 6 ft. 6 in. in diameter, having an open well, about 3 ft. 6 in. in diameter from the bottom to the top, to permit the material to be excavated by clam-shell buckets. Mr. Thomson.

After the caisson had penetrated some 75 ft., and was resting on what was supposed to be fairly good sand, it was filled solid with concrete to the top, which was 87 ft. from the cutting edge, making a solid concrete pier, 6 ft. 6 in. in diameter, from 12 ft. above ground to the cutting edge.

After this had stood for some time, a load of steel rails was gradually applied until a maximum of 10.24 tons per sq. ft. of base of the pier was attained.

A gradual settlement of $\frac{5}{8}$ in. resulted, and, when the load was removed, the rebound was $\frac{1}{4}$ in., leaving a supposed permanent settlement of $\frac{3}{8}$ in. As this settlement had been caused by applying 10.24 tons per sq. ft., and as the total weight of the bridge, with its live load, would not exceed 6 tons per sq. ft., it would seem that the piers would be perfectly safe. As a matter of fact, however, the jar of the trains started fresh settlement in a number of the piers, and this continued for about one year, when the maximum of 6 in. was reached. This was about 5 years ago; and since then there has been no trouble. Strange to say, the piers which settled were those which were supposed to rest on the best material.

The speaker once constructed a tunnel 7 ft. in diameter, by the poling-board method, under Cedar Street, New York City, and then ran a branch tunnel 4 ft. in diameter for 104 ft. up the street. The 7-ft. tunnel was just below the sewers and other pipes, and just above the water line at the bottom, as about 6 in. of very damp sand had to be handled. The work was done so carefully that there was absolutely no settlement in the street, and, as a matter of fact, nobody except those concerned in the construction knew that the tunnel had been built.

It might be interesting to mention the fact that in Michigan, where there are mining shafts 4 000 ft. or more in depth, it has been noted that heavy weights dropped from the top of the shaft never reach the bottom, as the revolution of the earth causes them to strike the side (always the same side) of the shaft, and become lodged there. This was first noticed when a very heavy weight was accidentally dropped from the top and it was feared that the men in the shaft must have been killed, but the men did not even know that anything had fallen, because it never reached the bottom.

James F. Fouhy,* Esq.—The speaker would like to know Mr. Parsons' opinion as to whether or not the rebound of the piles was due to looseness at the joints of the pile sections. Such rebound can hardly Mr. Fouhy.

* New York City.

Mr. Fouhy. be attributed to loose joints when the piles are concreted. The speaker has tested numerous piles recently before placing the concrete filling. The sections were from 12 to 16 in. in diameter, $\frac{5}{16}$ in. thick, and from 7 to 12 ft. long. Tests up to 40 tons were made with piles in clay, and 80 tons with piles on rock. In all the tests, the rebound was noted, and it is not unlikely that play at the joints was responsible therefor.

Mr. Harte. CHARLES RUFUS HARTE,* M. AM. SOC. C. E.—The speaker would like to know whether the rebound occurred immediately after the pressure was removed, or whether it was some time afterward that the piles showed a tendency to come up?

In connecting the Providence Division of the New York, New Haven and Hartford Railroad with the South Station, at Boston, Mass., in 1889, the necessity of maintaining traffic on the important streets crossed led to the use of a pile-driver with very short leaders, and sectional piles, which were made by sawing ordinary piles into 10-ft. lengths and fitting the lower end of each piece with a wrought-iron ferrule about 12 in. long, and a central dowel of 2-in. pipe. A special driving head, consisting of a heavy ferrule with a short section of pile, received the direct blow of the drop-hammer and protected the upper end of each section; as soon as a section was flush with the ground, this head was removed, a new section fitted on it, the head put on the upper end, and the driving continued until the pile was seated in the hard clay from 40 to 60 ft. below the surface. The material overlying the clay was salt marsh mud stiffened by the ashes, earth, and other filling material with which the Back Bay district had been reclaimed; it flowed laterally and vertically as displaced by the piles, forming a mound in some cases 2 or 3 ft. higher than the original surface, and, through the skin friction, opened the joints of the piles already driven, causing the tops to come up in some cases nearly 1 ft.

This adjustment of pressure extended over some little time, but, as a rule, if the piling of a group was tapped by the driver 48 hours after the last pile was driven, there was no further movement.

With sand, however, as in Mr. Parsons' case, the speaker would not expect such delayed action. The Boston fill had decided elasticity, which here would be lacking.

Mr. Connelly. JOSEPH A. A. CONNELLY,† ASSOC. M. AM. SOC. C. E.—If the speaker understood Mr. Parsons correctly, he has stated that the load used in testing the piles was from 40 to 50% in excess of the required load. He has also stated that the pile was jacked down under this excess load, was held in place by the jack, and that the load of the super-

* New Haven, Conn.

† New York City.

structure was then wedged hard down on the pile, so as to prevent any motion. The speaker presumes the motion referred to was the rebound of the pile. Mr. Connelly.

Assuming the required load on the pile to be 40 tons, the load under which the pile would be jacked down and held in place would be 60 tons. The speaker would like to know how a pile under a pressure of 60 tons can be held in place by a superstructure load of 40 tons. It is very probable that even 40 tons is in excess of the load which the pile actually receives from the building, while the 60 tons is actually placed on the pile by the jack.

It has been suggested that the rebound may be due to motion at the joints of the pile, but, in the speaker's opinion, this is not the case. On work of which he has had charge, steel casings, filled with concrete, were driven to a depth of 34 ft. These casings were made up of seventeen 2-ft. sections, and thus there were sixteen joints in each pile. As in the cases mentioned by the author, the piles rebounded about $\frac{1}{4}$ in. when the jacks were released. If all this rebound was due to motion at the joints, and was considered to be equally divided, the movement at each joint would be $\frac{1}{64}$ in.; this, in the speaker's opinion, is too small to lend much support to the theory that pile rebound is due to joint motion.

A statement has also been made that a pressure of 77 tons was sustained by an empty pile made up of short steel sections; this pile resistance, under conditions such as those outlined in the paper, seems to be high; one would be led to suspect that an obstruction had been encountered.

J. S. Branne,* M. Am. Soc. C. E.—The speaker wishes to ask Mr. Parsons' opinion as to the behavior of the steel-cased concrete piles. Mr. Branne.

It is stated in the paper that the piles rebounded after releasing the pressure exerted by the jack which had forced them down. It seems to the speaker that this rebound is due, in a large measure, to lack of skin friction in these piles—the surface being a smooth steel plate—and that this would not occur in piles with a rough surface, as in a concrete pile cast and seasoned before driving, or even in a wooden pile, the latter having more or less knots and irregularities. The material through which the piles were forced is stated to be coarse sand, and this should offer quite some resistance to rebound. The speaker believes that, in a soft clay soil, there would be a rebound, due to the elasticity of the soil and the lubricating influence of the moisture in the clay.

Referring to the jill frames which were driven forward with jacks, the speaker would like to know how large a section of frame was pushed forward at one time, that is, how wide a section; and also how much pressure was required to push such section forward? In case

* New York City.

Mr. Branne. of an unusual obstruction, as, for example, a large boulder, the speaker supposes that such obstruction would be removed by the laborers with picks and shovels.

Mr. Buel. A. W. BUEL,* M. AM. SOC. C. E.—The speaker would like to know whether it is possible that a part of the rebound is due to the elastic recovery of the pile itself?

With a modulus of elasticity, E_c, taken at 2 000 000, the elastic recovery of a pile, 14 in. in diameter and 40 ft. long, under a load of 40 tons, would be 0.01 ft., or $\frac{1}{8}$ in.

$L = 40$ ft.;
Diameter = 14 in.;
Area = 154 sq. in., nearly; and
$P = 40$ tons = 80 000 lb.

Then, if E_c is assumed at the usual value of 2 000 000, there will result:

$$f = \frac{P}{A} = \frac{80\,000}{154} = 520 \text{ lb. per sq. in.}$$

$$\text{Deformation} = \text{elastic recovery (nearly)} = e = \frac{f\,L}{E_c}$$

$$= \frac{520 \text{ lb.} \times 40 \text{ ft.}}{2\,000\,000} = 0.0104 \text{ ft., or } \tfrac{1}{8} \text{ in.}$$

The average final rebound, of the four tests in which it was recorded, appears to be 0.2715 in., or slightly more than $\frac{1}{4}$ in. The elastic recovery of the pile itself is shown to be just about one-half of this, if the modulus of elasticity is taken at 2 000 000. Considering the conditions under which the concrete is placed, it would not be surprising if the modulus were less than 2 000 000, in which case the elastic recovery of the pile itself would be a still larger proportion of the total final "rebound". The remainder of the final rebound—probably not more than $\frac{1}{8}$ in., and possibly less—might be just as well described and explained as the "elastic recovery" of the material supporting the pile, as to call it a "readjustment of the particles". In the last analysis, there may not be much distinction between the two descriptions or explanations, but if the phenomena can be explained by the action of well understood properties of matter, there would not seem to be any good reason for seeking new theories.

If the figures given by the speaker are correct, and the rebound is due, in about equal parts, to the recovery of the pile and of the material supporting it, then both would be of about equal importance. The records of the five tests indicate stress-strain relations not very different from those characteristic of concrete columns. This would naturally be expected, as both the concrete and the supporting material are imperfectly elastic and, like the concrete, the supporting material probably has a variable modulus of elasticity.

* New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

A METHOD OF DETERMINING A REASONABLE SERVICE RATE FOR MUNICIPALLY OWNED PUBLIC UTILITIES

Discussion.*

BY MESSRS. FRANK S. M. HARRIS, T. KENNARD THOMSON, AND W. B. YEREANCE.

FRANK S. M. HARRIS,† ASSOC. M. AM. SOC. C. E. (by letter).‡—Mr. Lippincott has taken a thoroughly commendable stand in insisting that municipalities enter a public utility field which is more or less adequately served by a privately owned utility under rate conditions equivalent to those confronting the private enterprise. It is only as a result of such an equitable attitude that private capital may be expected to "pioneer" in those fields into which the public is not for the time desirous of entering. It is decisions such as that in the hearing of the City and County of San Francisco in the matter of special crossing privileges for its Municipal Railways,§ in which the municipality was reduced to the standing of a private corporation, which have operated to remove the bitterest of the criticism heaped on the heads of utility commissions by the public service corporations which have been "regulated". Mr. Harris.

The writer has but recently completed an exhaustive survey of the whole franchise situation for the City of Oakland, Cal., in the course of which there was indirectly revealed the devious if not perilous path traversed by the average public utility company prior to 1900. The manifold injustices, at the hand of shifting political régimes under which they labored, were but equalled by the corrupt

* This discussion (of the paper by J. B. Lippincott, M. Am. Soc. C. E., published in September, 1916, *Proceedings*, and presented at the meeting of October 18th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† Oakland, Cal.

‡ Received by the Secretary, October 27th, 1916.

§ *Engineering News*, Vol. 74, p. 181.

Mr. Harris. advantage which they in turn took of the municipality. It is refreshing, therefore, to find set forth so fair a basis for square dealing between the municipality and the private corporation.

Mr. Lippincott, however, considers only the case in which the municipally owned utility exists side by side with, but completely independent of, the privately owned utility.

Of late years, an innovation is being written into the franchises of privately owned utilities, in which the municipality is an active partner in all development and extension programmes, as well as in the formulation of financial and operating policies. Such a provision is but a corollary of the principles advocated by Mr. Lippincott.

For the new blanket resettlement franchise, now being sought by the San Francisco-Oakland Terminal Railways in exchange for its 130 or more parcel franchises, the following provisions are found:

(1)—A board of control composed of one representative of the city and one representative of the company shall have jurisdiction over such matters as extension, outlay for equipment, allowance for depreciation, and the like; and

(2)—After payment of operating expenses, taxes, depreciation as fixed by the board of control, and a 6% return on its agreed physical valuation, at least 55% of the net revenue remaining shall be paid to the city.

These clauses are in addition to the usual machinery of the indeterminate franchise, providing for the taking over of the ownership by the city on 6 months' notice at the agreed physical value.

It would seem that, until such time as public ownership is the accomplished fact which it now bids fair rapidly to become, either an equitable rate-making policy for the municipal competitor or an implied co-operation between the municipality and the privately owned public utility are the essentials of any thoroughly satisfactory solution of the existing difficulties.

Mr. Thomson. T. Kennard Thomson,* M. Am. Soc. C. E.—Mr. Lippincott deserves the thanks of the Society for his very clear presentation of a most vital issue.

We are going through a formative stage at present with such subjects as socialism, suffragettism, unionism, public ownershipism, anarchism, and general radicalism, and the tendency of the country is to try everything, even including Wall Street speculation; but, fortunately—like an intelligent child who has burnt his fingers—the country profits from the expensive experience, and tries something else. For instance, a town will elect a Socialist mayor, and then snow him under at the next election. Again, a State will try the "referendum and recall", pass a dozen different and contradictory bills on

* New York City.

Mr. Thomson.

the same day, and then try to recall both the "recall and the referendum". The experiments which prove profitable will remain, and even a few, like suffrage, will undoubtedly stick, if adopted, whether really beneficial or not.

When it comes to public ownership, we have examples in New York City—the Staten Island Ferry, Brooklyn Bridge, etc.—which, as everybody knows, are not financially profitable. Even the Rapid Transit would not pay if entirely owned by the municipality. For what city would dare to pay a yearly salary of $100 000 or more to one man, even if he could earn many times that much for the tax-payers.

Ninety-nine men out of a hundred will say that no man is worth more than, say, $10 000 a year, and that he (that is, the other man) has dozens of men under him who could do the work as well or better for less money; and this in face of the facts found actually all over the world for it is hard to make people believe what they see.

To take a single example: The Intercolonial Railroad, one of the best built railroads in America when constructed by the Canadian Government, enjoyed an absolute monopoly between Halifax and Quebec for many years. True, the country was larely undeveloped, but not as much so as the vast Canadian Northwest was when the late Sir William Van Horne finished the Canadian Pacific Railroad; but Van Horne saw to it that the great prairies were developed to build up his road; whereas the men who ran the Government-owned Intercolonial stuck strictly to the business of operating the road, instead of creating business to make the road pay, with the result that for some 40 years the road did not even earn operating expenses, let alone pay taxes or interest on the money.

The speaker, when recently talking to a prominent Canadian, suggested that, if the Government had engaged a man like the late Sir William Van Horne, or the late James J. Hill, F. Am. Soc. C. E., or any one else of that caliber, and offered such a man a salary of, say, $50 000 plus a bonus, he would have earned his salary, a bonus of several hundred thousands a year, after having paid the Government ample taxes and a good interest on the money invested in the railroad, and, at the same time, would have developed the adjoining territory, thus benefiting the country from one end of the Dominion to the other.

My friend contradicted me, saying that the Government at one time really did engage a man capable of getting these results, and that he at once began by examining the freight rates, which disclosed the fact that many of them were ridiculously low. He ordered the rates raised and made the same for all. To make a long story short, his days were numbered, and the road ran on as before.

On repeating this story to a very powerful newspaper owner, the speaker was told that such a state of affairs was quite justifiable,

Mr. Thomson. because it paid to run a road at a loss for the sake of building up the country. This, however, is exactly what such management never does, as it considers its duty done when it operates the road.

This is no reflection on the staff of this railroad, which is a very competent one, whose work is well done—that is, as far as it has any authority to work—but one man with the necessary power, and inducement, could take the same staff and turn a financial failure into a great financial success, thereby benefiting the entire country.

To take another example, nearer home; a fatal mistake was committed in the construction of our magnificent $150 000 000 Barge Canal (with political "poorsight") in the beginning when it was made a barge canal, instead of a ship canal. As it is, no boat with a clearance of more than 15 ft. above the water can pass under the bridges and use the canal. This mistake was not made on the Canadian canals, which, with the same or less depth of water as the Barge Canal, are able to pass vast fleets of masted vessels.

It now remains to be seen whether the same lack of judgment will be displayed in the operation of the Barge Canal, as on this depends the profit or loss on the enormous sums paid by the people for this undertaking. If the canal is properly managed, the State will enjoy far-reaching results. Moreover, if a man is employed who has the ability and is given the power to make business for the canal, as well as to see that it is properly operated, the State will be handsomely rewarded for the sums expended for the construction and maintenance of this work, which in many ways far surpasses the Panama Canal.

It is just as if the State were to build a number of huge skyscrapers and then trust to luck that the people would find, use, and pay for them. Needless to say, the privately owned buildings adjoining, run by wide-awake business men, who would go after their tenants, would be filled at once, while the State buildings would be nearly empty, and of course operated at a loss.

It seems to the speaker that by discussing actual cases more progress will be made than by the expression of purely theoretical opinions, and that the ultimate result will be proper Government regulation, instead of Government operation or ownership.

Last spring, at a political meeting, called for the purpose of explaining the extra $19 000 000 appropriation in New York State, the speaker, after the regular speakers had finished, begged to draw attention to the great difference between the City and State on the one hand, and an ordinary business organization on the other; the business man has to earn the money he spends, while the City and State spend the money which they force the tax-payers to contribute.

The speaker then pointed out two projects which, if encouraged by the City and State, would result in putting both on a business basis. The City and State would receive more than $30 000 000 outright and

Mr. Thomson.

a rental of at least $2 000 000 a year, to say nothing of enormous indirect benefits. The projects are "A Really Greater New York", and a "New Niagara Falls, of 2 000 000 h.p."

Mr. Yereance.

W. B. YEREANCE,* M. AM. SOC. C. E.—The author has stated clearly some of the problems to be met in the municipal ownership of public utilities. It is assumed that he has contemplated as well municipal operation of those properties or plants. Of course, it may be, and so happens, that some properties are municipally owned but privately operated by private corporations.

An insolvent or mismanaged utility is a handicap to the progress of the community or district it serves. A utility should be in receipt of a sufficient revenue to meet, under proper management, all operating expenses (including maintenance, depreciation, taxes, and a sufficient reserve as insurance against catastrophe), and a reasonable return on the fair capitalization of an adequate plant. This revenue is or should be produced practically in its entirety by the rates charged for service. Rates are or should be so determined that each beneficiary contributes to the total necessary revenue of the utility only his just and due proportion for benefits received. If the plant be ill-adapted to the community's needs, or unnecessarily expensive, or the management extravagant or incompetent, or the securities inflated, the rates to produce the needed revenue will be unnecessarily high or unreasonable, either throughout or for certain classes of the service. Therefore, if minimum rates are to be enjoyed, the property or plant furnishing the service must be designed and constructed wisely and economically and operated efficiently. To the extent that these conditions have not been met, the rates will be above a possible minimum.

For a given standard of plant and service in a given community, the rates for that service should be lower under municipal than under private ownership and operation. Yet, despite some highly flattering operating statements issued periodically, the speaker knows of no situation on this continent to-day where municipally operated utility service is being rendered at actually lower rates than are or should be charged for similar service by private enterprise. If politics and political considerations can be eliminated in the development and operation of a public utility, then and then only will be possible the successful establishment of actual rates that to-day are merely a dream of the theorist. Evidence is not lacking that there are those who realize the situation, and it may be that at some future period the ideal will be realized. However, those now interested in the private administration of public utilities need have no fear that their retainers or jobs are in immediate danger. If that ideal time comes when the public utilities can be removed from adverse political influences, then public utilities should be municipally owned and operated. Private

* New York City.

Mr. Yereance. enterprise has its own problems to meet in the conduct of public utilities, but it could not live under many of the practices now associated with municipal ownership and operation.

The author has referred to the inherent right of a community to serve itself, but calls attention to the broad question of equity involved where such contemplated municipally owned and operated service would introduce competition with a private plant, established in good faith, and serving the public adequately at reasonable rates. Some regulatory bodies have recognized the ethics of such a situation in their decisions, and the demands of simple justice—to say nothing of policy—have been met; other commissions have not been so far-sighted.

Some 3 or 4 years ago a campaign favoring municipal ownership was waged vigorously by some of the ambitious politicians in one of the Southern States. At that time the speaker was retained to protect a considerable investment of northern money in a combined electric light and gas property in one of the cities of that State. The electric plant was probably the most up-to-date of any in a community of that or considerably larger size in the United States; the gas plant was not in quite such good shape, but both were fully adequate and the rates charged were lower than prevailed—under Commission authority and at some places under more favorable conditions—in any community of similar size in that or adjoining States. The good faith of the investors was apparent in both the condition of the property and the amount of money actually invested, yet the political elements favoring municipal ownership practically forced the company into a desperate position, whence it was extricated with the greatest difficulty.

The attitude of the commission, the public press, and many of the people, was such as to discourage the investment of outside money in that locality; some are now beginning to realize the short-sightedness of that attitude when new money is desired but not procurable. Certainly, in the light of these facts, no honest consultant could or would recommend investment where such conditions prevail.

Reference has been made to a certain steam railroad, governmentally owned and operated. Located through thin traffic country, its value would seem to be largely military rather than economic. Such property needs a higher grade of management than does one which is more favored; yet the road in question has always been notoriously politically mismanaged. It could have been operated better with one-half the number of men shown on its pay-rolls. Instead of the two or three—as mentioned by Mr. Thomson—there were at least ten times that number of good railroad men in the United States who, with free hands, could have developed the full earning capacity of the property.

AMERICAN SOCIETY OF CIVIL ENGINEERS
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PAPERS AND DISCUSSIONS

A COMPLETE METHOD FOR THE CLASSIFICATION OF IRRIGABLE LANDS

Discussion.*

By T. Kennard Thomson, M. Am. Soc. C. E.

T. Kennard Thomson,† M. Am. Soc. C. E. (by letter).‡—This clean-cut paper is of especial interest to the writer because he was on the survey for the first railroad, the Canadian Pacific, to be built in that section of the country, 33 years ago. Mr. Thomson.

At that time nobody ever expected to see this road pay for itself, as it was built as a political necessity to keep British Columbia and the great Prairie Provinces in the Dominion.

An old farmer described the conditions then as follows: "Forty degrees below zero, 50 miles from water, 500 miles from fuel, God bless our home."

The paper would be even more interesting, if made a little more general by stating, for instance, the quantity of water required for irrigation, and whether the supply is continuous or intermittent during the summer. As the water comes from the mountains, the writer assumes that the supply would be cut off by the ice in winter. For instance, even the North Saskatchewan, at Saskatoon, a mighty river in summer, is practically dry in winter.

It would also be interesting to know what the good and poor lands sell for, before and after irrigation.

The alkali lands referred to remind the writer that he heard only last week why his hair had turned white when quite young. It was discovered, not very long ago, that all young men in the Canadian

* This discussion (of the paper by F. H. Peters, Assoc. M. Am. Soc. C. E., published in September, 1916, *Proceedings*, and presented at the meeting of November 1st, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New York City.

‡ Received by the Secretary, November 1st, 1916.

Mr. Thomson. Northwest have become white-haired because of the alkali in the water and also because of the quantity of ammonia used for purifying the water.

The author states that the climatic conditions are the same as in Northern Montana, but as the range of temperature is more interesting than the mean, why not state what they are?

Is it not true that the depth of the rich top soil is 15 ft. or more in vast areas of the Canadian Northwest? It may be more modest not to extol the richness of the soil, etc., but, at the same time, one would like to know the facts. The price for excavation and fill, 12 cents (as stated by the author), seems to be remarkably low, especially as the quantities of material moved in any one spot are so small.

The sections of the cuts and excavations are so small, and the wooden superstructures are so light, that one wonders if they do not require very considerable repair every spring.

The Canadian engineers, instead of using blue or black prints on paper, make black prints directly on cloth, and these can be placed in a pocket or bag as readily as a handkerchief; and the writer is surprised that such a great improvement has not already been generally adopted by American engineers.

Table 3, showing the increased value of land each year due to irrigation—an increase from 0 for wheat to $200 an acre for potatoes—is exceedingly interesting. In New York State, frost in a single night will sometimes destroy all the crops; and then a month or more of good weather will follow with no frosts. Is this the case in Alberta?

Some day it will be possible to generate by electricity sufficient heat for a night or two to afford sufficient protection from such frosts; and it will be possible even to go further and, by artificial heat and light, produce two crops where only one grows now.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES ADOLPHUS CALDWELL, M. Am. Soc. C. E.*

DIED AUGUST 31ST, 1916.

Charles Adolphus Caldwell, the son of Oscar Adolphus Caldwell and Carrie B. Caldwell, was born in Macon, Bibb County, Ga., on October 18th, 1866.

He began his engineering studies in 1882 at Vanderbilt University where he remained two years. In 1884, he entered Rensselaer Polytechnic Institute, Troy, N. Y., and was graduated in 1888 with the degree of C. E.

Shortly afterward Mr. Caldwell began his professional career under F. T. Dabney, Chief Engineer of the Central of Georgia Railroad, on the extension of this road from Savannah to Americus.

In 1890, he was made Assistant Engineer on the St. Augustine and North Beach Railroad, in Florida, from which position he resigned to return to Macon, to accept an appointment in the office of the City Engineer. In 1894 he was associated with Capt. J. W. Wilcox, Assistant Engineer on the construction of the Fort Valley Water-Works, and as Principal Assistant to the City Engineer on the construction of 32 miles of sanitary sewers in Macon, Ga.

In 1898, he was the Principal Assistant Engineer, in charge of construction work, for the Macon Gas Light and Water Company, during the construction of a 5 000 000-gal. filter plant and a new pumping station.

In 1899, Mr. Caldwell designed and supervised the sanitary sewer system for the City of Valdosta, Ga., and, in the same year, as Chief Engineer, designed and constructed a water-power development for 1 000 h.p., at Juliet, Ga., on the Ocmulgee River. Here he also built a 3 000-spindle cotton mill, and a grist mill with a daily capacity of 8 000 bushels for the Juliet Milling Company.

From 1899 to 1907, he was engaged in the general practice of his profession, with offices at Macon, Ga. During this time, he had charge of a large amount of general engineering work, including a number of highway bridges, a sanitary sewer system for Forsyth, Ga., and was associated with J. N. Hazlehurst, M. Am. Soc. C. E., in making the appraisal of the existing water-works property of the Macon Gas Light and Water Company, and designing a proposed municipal water-works system of 10 000 000 gal. daily capacity. In 1910, he and Mr.

* Memoir prepared by G. R. Solomon, M. Am. Soc. C. E.

Hazlehurst represented the City of Macon before the Board of Arbitration which fixed the value of this property at $699 000, when the plant was purchased by the City.

In 1911, Mr. Caldwell prepared reports and plans on a 10 000-h.p. hydro-electric development on the Ocmulgee River, near Juliet, and was also engaged, as Chief Engineer, on the remodeling and extension of the water-works system of the City of Macon.

In addition to his engineering work, Mr. Caldwell was interested in several manufacturing concerns as an officer and decorator, and his opinion was always sought and valued because of his fair-mindedness. He was universally liked and trusted, and his death is a decided loss to the Profession.

He was unmarried, and is survived by one sister, Mrs. John B. Birch, of Macon, Ga.

Mr. Caldwell was elected a Member of the American Society of Civil Engineers, on September 5th, 1911.

ARTHUR HIDER, M. Am. Soc. C. E.*

Died July 28th, 1916.

Arthur Hider was born in London, England, on February 29th, 1844, and died at his home in Greenville, Miss., on July 28th, 1916. He was the son of James and Maria (Dear) Hider. In 1853, when he was nine years of age, his family moved from England to London, Ont., Canada. He received his early education in the schools of the latter place and afterward taught school there for a while. In 1864, at the age of twenty, he went to Cleveland, Ohio, where he began the study of engineering, as a private pupil, under Peter Emslie, a civil engineer, with whom he spent about one year.

In 1866, Mr. Hider was employed as a Draftsman by George Steuly, City Engineer of Louisville, Ky., and, after one year's service in that position, was appointed Assistant City Engineer and given charge of the public works in one-half of the city. After the death of Mr. Steuly, in 1869, Mr. Hider was continued in the same position under the late I. M. St. John, M. Am. Soc. C. E., who succeeded Mr. Steuly as City Engineer, until 1871, when the late Thomas P. Shanks, M. Am. Soc. C. E., became City Engineer. Mr. Hider was then appointed Principal Assistant City Engineer, and given charge of all improvements made by the city, except in the Sewer Department. He continued to serve in this position until some time in 1876, when Mr. Shanks was retired from office, and he, as the Principal Assistant, along with him.

* Memoir prepared by Charles H. West, M. Am. Soc. C. E.

From 1876 to the early part of 1879, Mr. Hider was engaged with his former Chief, Mr. Shanks, in engineering and contracting work, during which time they constructed a reservoir at Anchorage, Ky., and, for about one year, were engaged on masonry work at the new reservoir at Louisville, Ky., both of which were under the supervision of the late Charles Hermany, Past-President, Am. Soc. C. E., Chief Engineer of the Louisville Water-Works.

Mr. Hider entered the Government service in 1879, and, for a short time, was employed under Charles R. Suter, M. Am. Soc. C. E., Major, Corps of Engineers, U. S. Army (now Brigadier-General, *Retired*), in making hydrographic surveys and physical observations on the Mississippi River, near Arkansas City, Ark. Maj. Suter was appointed a member of the Mississippi River Commission, which body was created by Act of Congress, dated June 28th, 1879, and Mr. Hider was assigned to duty under Lieut. Smith S. Leach, Corps of Engineers, the Secretary of that Commission. From October, 1879, to November, 1880, he was engaged in making hydrographic surveys and collecting physical data on the river near Lake Providence, La., and, later, had charge of a party taking slope observations along the river between Cairo, Ill., and New Orleans, La.

The Commission was now ready to begin construction, and, in September, 1881, Mr. Hider was assigned to duty as one of the Assistant Engineers in the Third Mississippi River District, extending from the White River to a few miles below the mouth of the Yazoo River. The Engineer Officer in charge of the district was Lieut. W. L. Marshall, who, later, became Chief of Engineers, U. S. Army. During the few years that Mr. Hider served under this officer, they learned to regard each other highly, and there ever after existed a friendly feeling between them.

At the time when Mr. Hider entered the Government service under the Mississippi River Commission, very few reliable data were available as to the regimen of the Mississippi, and few, if any, precedents of practical value as guides in a project of such character and magnitude as that which had been assigned to the Commission. His first service was in connection with surveys and observations to collect data necessary for a study and development of plans for the improvement of the river, but when it was decided to begin construction, he was transferred to that work, and soon became the Principal Assistant Engineer in charge of all revetment and other work of channel improvement in the Third Mississippi River District, serving continuously in that position until his death.

The first works of construction were necessarily experimental in type, as were also the various kinds of plant needed for carrying on the work. Mr. Hider was intimately connected with each step in the

development of suitable types of construction, and also had much to do with the design and construction of towboats, hydraulic graders, and the various other items of plant required for the work in the Third District. He took great interest in the development of plans for the improvement and control of the river, and no small share of credit for successful work is due to his faithful, untiring, and patient attention to the duties of his position. He came to be regarded as an authority on bank revetment and other channel works, and his counsel in such matters always had weight.

Mr. Hider was connected with levee construction only in a limited way, but he was a close observer of what was going on in that line, and had very clear views in regard to that work.

In addition to his work under the Mississippi River Commission, he, occasionally, while on leave of absence and during spare time, served as Consulting Engineer in connection with municipal improvements, some of which were the design and construction of water-works systems at Greenville, Miss., Lake Providence, La., and other places; he was expert member of the Committee to determine the value of the water-works system of Memphis, Tenn., when that system was taken over by the City of Memphis.

Mr. Hider enjoyed remarkably good health until the last three years of his life. During the spring of 1913, while temporarily in charge of the work of closing the crevasse in the levee near Beulah, Miss., he was exposed to very inclement weather, with the result that he was taken seriously ill and never after entirely regained his health. He was unable to attend to active duties for more than a year prior to his death, but he continued to go to the office and, except during the the last few weeks, he could be found at his desk every day when he was strong enough to leave home.

Mr. Hider was indeed a veteran of the Engineer Service of the Mississippi River. There being no provision in law for the retirement of civilian engineers in the service of the Government, he, like many others, remained on duty until advanced in age and literally worn out.

He lived to see nearly all the Engineer Officers under whom he had served in the early days on the river retired with high rank, and, as these men were near his own age and counted among his friends, he was always pleased to hear of any good fortune that came to any of them.

In later times, it was his province to serve under District Officers who were many years younger than himself, and to each of these he gave loyal assistance. They, in turn, recognized his ability and ripe experience, and his candid manner and earnest attention to duty never failed to win their confidence and esteem.

He was a good organizer, and believed in strict discipline. He recognized authority in those above him, and demanded obedience to orders from those under him. He was highly respected by his subordinates, and, though they dreaded his displeasure, they delighted in his approval, for he was just in his dealings with them and ever ready to give credit where it was due. It was a pleasure to him to advise and otherwise help along young engineers who appeared to be earnest and appreciative of his guidance.

Mr. Hider took an active interest in the civic affairs of the community in which he lived. There was no pretense and very little diplomacy in his nature, and he was outspoken in his opinions. He was well informed on many subjects other than his profession, and had a fine appreciation of music and art.

Mr. Hider was a member of the Protestant Episcopal Church, and though not outwardly a devout churchman, he had deep religious convictions. He loved the quietude of his home life, and was a devoted husband and kind father, and although he seemingly cared but little for social life in general, he was fond of the companionship of his friends.

He was married in Louisville, Ky., on October 6th, 1873, to Emma K. Anderson, who, with two daughters and three sons, survives him.

Mr. Hider was elected a Member of the American Society of Civil Engineers on September 7th, 1881.

WILLIAM RIDLEY NEELY, M. Am. Soc. C. E.*

DIED APRIL 11TH, 1916.

William Ridley Neely, the son of Robert Johnson Neely and Elizabeth Norfleet Ridley, was born on August 20th, 1872, in Portsmouth, Va. He was educated at private schools, first at a "Dame's school" in Portsmouth, and then at Norfolk Academy, of Norfolk, Va. He also attended the University of Virginia from 1888 to 1890.

The early years of Robert Johnson Neely, his father, were spent at Newton, Pa., where the old Neely family homestead, built before the Revolution, is now the property of the Daughters of the American Revolution. Early in life he went to Portsmouth, Va., where he was engaged as a lumber manufacturer. He became so identified with the South that he fought with the Confederate Army all through the Civil War. Mr. Neely's mother, Elizabeth Norfleet Ridley, is a collateral descendant of Bishop Ridley who was burned to death for

* Memoir prepared by James F. Sanborn, Assoc. M. Am. Soc. C. E.

religion's sake in the time of Mary Tudor. She was born and brought up on a plantation near Portsmouth, Va., and was educated in convents in South Carolina and at Richmond, Va. Her father was a well-known landed proprietor of his section, a very fine type of the ante-bellum country gentleman. William Ridley Neely's parentage and traditions were all of the South, and he always took great pride in the development of his home State.

Mr. Neely entered the service of the United States Engineer Department, in the Vicksburg District, in October, 1891, and remained in the employ of the Government for 8 years, being engaged mainly on soundings, precise level work, topographical surveys, and computations, along the Mississippi and tributary rivers. In March, 1899, he was furloughed to take service with the Isthmian Canal surveys in Nicaragua, and remained there until April, 1900, at which time he returned to the Vicksburg District and remained until 1904, in charge of test borings and drafting plans and designing locks, dams, and other structures. In connection with the test borings in the bed of the Ouachita River, several deep borings were made to determine the geological structure of the valley, notably at Catahoula Shoals, Columbia, Rock Row Shoals, Jacks Island, and Newport Landing. The information obtained has been utilized in the later reports on the geology of Louisiana. The plans for the Ouachita locks and dams embraced the designing of foundations in treacherous material, concrete walls subject to earth and water pressure, steel lock gates, and a variety of operating machinery, as well as the solution of many hydraulic problems.

In May, 1904, Mr. Neely was furloughed to take up engineering work at the West Point Military Academy, where he remained until October, 1906, on work connected with the increase of the water supply for the military reservation there. This involved the location of the pipe line through most difficult country and its actual laying, the length of the line being approximately 6 miles, and the pipe 20 in. in diameter. Mr. Neely did most of the field work connected with this project, and his superior officer considered the service which he rendered very satisfactory. He also assisted in designing the filters which were to be built at West Point.

In October, 1906, Mr. Neely entered the service of the State of New York, as Assistant Engineer in the Engineering Department of the Barge Canal, and continued with that work for more than two years. D. A. Watt, M. Am. Soc. C. E., who was at that time Assistant Engineer, in charge of the Designing Office of the New York State Barge Canal, says:

"He [Mr. Neely] assisted me during that time in preparing the plans for some of the chief sections of the canal, such as the cross-

country line just west of Rochester, which comprised two high-lift locks, as well as very heavy cuts and embankments; the line through Phœnix on the Oswego River; and the line through Little Falls. The latter included a lock of 40½ ft. lift, as well as difficult work in carrying the canal through a narrow gorge and along the side of a rock bluff overhanging the Mohawk River. I found Mr. Neely an able man. He was a very hard worker and had originality and accuracy, and I was very sorry to lose his services. He left to accept a more promising position with the State Water Supply Commission."

In the spring of 1908, Mr. Neely was employed as Resident Engineer in charge of two field parties making topographical surveys and maps of the basin of the proposed big Sacandaga Storage Reservoir, near Northville, N. Y., as well as surveys of the storage possibilities at Piseco, Pleasant, and Schroon Lakes. In 1909, he was re-engaged by the State Water Supply Commission, but soon after resigned. Horace Ropes, M. Am. Soc. C. E., speaks of him, as follows: "Mr. Neely was an active and industrious worker, an agreeable person, well liked by those associated with him."

From June, 1909, to April, 1913, Mr. Neely was employed by the Board of Water Supply of the City of New York on the construction of Section 1, Wallkill Division, of the Catskill Aqueduct, at New Paltz, N. Y., of which section he had charge. The work consisted of a standard type concrete aqueduct, in cut and cover, along a strip on the east slope of the Shawangunk Mountains, mainly in rock cut, and a grade tunnel driven toward the north under Bonticou Crag to meet the tunnel driven from the other side of the range. In contrast with the soft-ground problems of his early experience along the lower Mississippi River, Mr. Neely greatly enjoyed the work and methods used for the hard-rock excavation, timbering, and concrete construction in the tunnel, and the difficulties encountered in open-cut work. In connection with his duties of supervising the construction, he worked out several problems of design for special structures and unusual conditions, and also had the gratification of executing this work. He was a member of the Catskill Aqueduct Association and took great interest in his relations with the engineers he met on that work.

On April 10th, 1913, Mr. Neely resigned to enter the contracting field. He built several miles of the special concrete post and wire fences along the Aqueduct, which occupied him until the spring of 1915. At the time of his death on April 11th, 1916, he was living in Portsmouth, Va.

He was married on February 20th, 1901, to Annie Calvert Jones, of Vicksburg, Miss.

Mr. Neely was a member of the General Alumni Society of the University of Virginia. He was elected a Member of the American Society of Civil Engineers on July 9th, 1906.

WILLIAM RODNEY PATTERSON, M. Am. Soc. C. E.*

Died July 19th, 1916.

William Rodney Patterson was born at Effingham, N. H., on November 4th, 1854.

He was graduated from Dartmouth College in 1876, and, within a few months, was associated with the late Enos M. Barton, of the Western Electric Company. For many years, Mr. Patterson was the Plant Engineer of the Western Electric Company, and had direct charge of the construction and maintenance of all its many buildings, not only in the United States, but also of its various plants in Europe and the Orient.

He was directly responsible for the invention and perfection of the dry-core telephone cable now so generally used throughout the civilized world, as well as of the process of extruding a lead sheath over the cable. He took out more than 100 patents in connection with the development of the telephone cable.

In 1911, Mr. Patterson retired from the Western Electric Company and, until his death, which occurred on July 19th, 1916, after an illness of some months, he was senior member of the firm of Patterson and Davidson, Consulting and Designing Engineers, in Chicago, Ill.

He was a man of quiet reserve, but was nevertheless endowed with an interesting and genial personality, and any one who came in contact with him, in business or socially, became at once his stanch friend. By nature a man of the simplest tastes, he was a great reader and a keen observer. His hobby, during his spare moments, was the preparation of colored lantern slides of architectural and engineering objects, and his library contains many thousands of such slides colored by his own hands. He was a great traveler, and, during the latter years of his life, spent at least one-half his time on foreign shores.

As an executive, Mr. Patterson had few superiors. He had the peculiar natural gift of being able to select his assistants and of having the wise judgment of transferring to them authority and holding them responsible for results, he himself not devoting his valuable time to minute details of work or organization.

While in the employ of the Western Electric Company, he was recognized as its construction genius. He had seen the Company develop from about 25 employees until, at the time of his retirement, they numbered more than 50 000; and in that time the yearly sales had increased from a few thousand to about eighty million dollars.

Engineers will remember Mr. Patterson in connection with the development of the telephone industry, as without doubt its rapid

* Memoir prepared by F. E. Davidson, M. Am. Soc. C. E.

development has been due more directly to the invention and perfection of the dry-core telephone cable than to any other one thing.

Mr. Patterson was elected a Member of the American Society of Civil Engineers on May 4th, 1909.

FRANK EDSON SHEDD, M. Am. Soc. C. E.*

Died September 22d, 1916.

Frank Edson Shedd was born in Sharon, N. H., on July 18th, 1856. He attended the Conant High School of East Jaffrey, N. H., and entered Dartmouth College, from which he was graduated in the Class of 1880.

After a year of teaching, as Principal of a high school, Mr. Shedd entered the service of the United States Coast and Geodetic Survey, where he remained for a year, his work being on the charting of the coast of Maine. In 1882, he left the service of the Government to take up civil engineering in Lowell, Mass.

In 1886, Mr. Shedd had charge of the erection of the Washington Mills, at Lawrence, Mass., at that time one of the largest mill construction propositions which had ever been undertaken. These mills are now owned by the American Woolen Company.

In April, 1887, he became a member of the staff of Lockwood, Greene and Company, the engineering firm which had designed the Washington Mills, and two years later was made First Assistant to Mr. Stephen Greene, then the sole member of the firm. From that time until his death, Mr. Shedd maintained an intimate connection with that organization.

On January 1st, 1901, on the incorporation of Lockwood, Greene and Company, Mr. Shedd became a Director and the Vice-President of the firm, and held both these positions until his death. He was a Civil Engineer of high standing, and had designed many large mills and hydraulic plants in various parts of the United States and Canada, having been considered one of the leading authorities in this country on hydraulic developments.

Mr. Shedd was a man of varied interests; a member of the Boston Society of Civil Engineers and of the American Society of Mechanical Engineers, he was also a member of St. John's Lodge, A. F. and A. M., of Boston, a Companion in the Mount Vernon Royal Arch Chapter, and a member of the Second Parish Congregational Church, of Dorchester, Mass.

* Memoir prepared by Mr. Frank W. Reynolds, of Lockwood, Greene and Company, Boston, Mass.

Mr. Shedd was also a member of the New Hampshire Historical Society and a life member of the New England Historic Genealogical Society. He was the founder, as well as the Secretary and Treasurer, of the Shedd Family Association, and designed the handsome monument—erected at Shedd's Neck, in Quincy, Mass., three weeks prior to his death—by the Shedd Association, in honor of the first ancestor of the family in America. Having been for many years much interested in genealogical research, he had collected many valuable data regarding the Shedd descendants in America, and was making plans, when taken sick, looking toward the early publication of a genealogy of the family.

Mr. Shedd was a thorough, painstaking engineer, of retentive memory, wise judgment, and tireless industry; a modest unobtrusive gentleman of sterling character. One of his friends says of him:

"He was a high-minded citizen and represented the highest ideals of human life; he rendered a large service to his fellow-men; he was an honor to his Profession and has left behind him a name which ought to be an inspiration and help to us all for higher and better things."

During his illness, which covered the last six months of his life, Mr. Shedd suffered much, but bore his sufferings with great fortitude, and attended to many affairs up to the very last. He died at his home in Dorchester, Mass., on September 22d, 1916, leaving a widow and one son.

Mr. Shedd was elected a Member of the American Society of Civil Engineers on February 6th, 1907.

THEODORE VOORHEES, M. Am. Soc. C. E.*

Died March 11th, 1916.

Theodore Voorhees, eldest son of Benjamin F. Voorhees and Margaret E. Sinclair, was born in New York City on June 4th, 1847. Mr. Voorhees was a direct descendant in the male line from Stephen Coert Van Voorhees, who came to America from Holland, settling at Flatlands, Brooklyn, N. Y., in 1660. His mother was of Scotch parentage, the Sinclairs having come to America in 1835.

He received his education at Anthon's Grammar School, New York City, Columbia University (where he entered the class of 1868, but left in full standing in 1866), and the Rensselaer Polytechnic Institute, at Troy, N. Y., which he entered in 1866 and from which he was graduated in June, 1869. One month later Mr. Voorhees entered

* Memoir prepared by Samuel T. Wagner, M. Am. Soc. C. E.

the service of the Delaware, Lackawanna and Western Railroad, as Engineer on the extension from Great Bend to Binghamton. So successful was his work and so progressive were his methods, that in less than 2 years he was made Superintendent of the Syracuse, Binghamton and Oswego Division of this railroad. He held this position for 2 years, and then returned to the Engineering Department of the main road, with headquarters at Scranton, Pa.

Although the love of engineering was undoubtedly responsible for this move, Mr. Voorhees' ability as an operating official, which continued throughout his life, had already developed, and this drew him into the Transportation Department of the Delaware and Hudson Canal Company, in December, 1874. Three months later he was made Superintendent of the Saratoga and Champlain Divisions, a position which he held for more than 10 years. He resigned on October 20th, 1885, to become Assistant General Superintendent of the New York Central and Hudson River Railroad. On March 1st, 1890, Mr. Voorhees was made General Superintendent of this road, and, in 1891, was also appointed General Superintendent of the Rome, Watertown and Ogdensburg Railroad Company. While General Superintendent of the New York Central and Hudson River Railroad he saw his road adopt the controlled manual block signal system on its main line from New York City to Buffalo, N. Y. This was one of the most radical advances in railroad signal practice up to that time. At about the same time (1891), the New York Central put on the Empire State Express, with the phenomenal run of 440 miles in 8 hours, or 55 miles an hour. Mr. Voorhees was the operating head of this achievement, which advertised the New York Central all over the world.

Largely on account of his combined ability as a railroad engineer and operating official, he was made Vice-President of the Philadelphia and Reading Railroad on February 1st, 1893.

He was called to his new duties when but 46 years of age, and at a most critical period of the railroad's history. Emerging from a state of financial depression, after having passed through several receiverships, the road was in a condition of physical disability. So bad were the conditions financially that, in 1896, the property was sold under foreclosure proceedings. Mr. Voorhees was the operating head during these troublesome times, and was one of the foremost factors in the development of the property of the company. This development was entirely intensive, as the following figures will show:

	1893.	1915.
Mileage	1 170	1 120
Revenue ton-mileage.......	1 739 000 000	3 141 026 000
Passenger mileage.........	240 488 000	360 468 000
Earnings	\$22 986 000	\$46 715 000

These figures show a great development in the freight service, but Mr. Voorhees was also instrumental in perfecting the passenger service, and this will always remain as a monument to him. On May 8th, 1914, he was elected President of the road, succeeding the late George F. Baer.

He was also President of the following subsidiary railroads: Philadelphia, Newtown and New York; Philadelphia and Reading Terminal; Philadelphia and Chester Valley; Philadelphia, Harrisburg and Pittsburgh; Tamaqua, Hazelton and Northern; Reading, Marietta and Hanover; Dauphin and Berks; Philadelphia and Frankford; Schuylkill and Lehigh; and the Williams Valley.

He was a Trustee of his Alma Mater, the Rensselaer Polytechnic Institute, a member of the Holland Society of New York, the Century Club of New York, and St. Nicholas Society of New York; the Huntington Valley Country Club, Racquet Club, Philadelphia Club, and Automobile Club of Philadelphia. He was also a member of Psi Upsilon Fraternity.

One of the honors conferred on Mr. Voorhees was his election to the Vice-Presidency of the American Railway Association in 1904. He was also a Director of the Market Street National Bank of Philadelphia.

He was married, on September 19th, 1871, to Sarah V. Gould, daughter of Judge George Gould, of Troy, N. Y. She died on August 7th, 1872, and on February 4th, 1874, in Syracuse, N. Y., he married Miss Mary E. Chittenden, and is survived by a brother and by his widow, five sons, and three daughters.

It has been said of him:

"Theodore Voorhees belonged to a good school of railroad men. He had a conscience and he had ability. Regarded by many as cold and unapproachable, he was, nevertheless, extremely well qualified to solve all those larger transportation problems which in recent years have vexed the public mind. The dead President of the Philadelphia and Reading Railway was one of these, and an important one, who helped raise the Company from a condition of financial weakness into a state of affluence. By doing that he, with his associates, made their railroad of infinitely greater service to the country it serves than it had ever been during its years of financial ill luck. Mr. Voorhees knew railroading through and through, knew what it had to do to meet popular support and what it had to do to maintain its own self-respect and ability to serve. Alert and keen, industrious and honest, intelligent and full of courage, he could not fail in this generation of vast business development to rise to one of the conspicuous railroad positions of the world."

Another said:

"As a man, there is much to be said of Mr. Voorhees. Of austere presence and striking personality, he commands the respect and esteem

of all who come in contact with him. He is a man of very few words. He has always time to listen, and treats his subordinates with the utmost courtesy and respect. His friends all testify to his loyalty and kindness. Those who have had an insight into his private life have characterised his devotion as extraordinary."

For a number of years Mr. Voorhees was a Vestryman of St. Luke's Protestant Episcopal Church, Philadelphia, in which he felt a great interest.

His funeral was held at his home in Elkins Park on Tuesday, March 14th, 1916. About 400 prominent railroad officers, bankers, and professional men were present. As a mark of respect, all trains throughout the Reading System were brought to a stop for one minute, at 11 A. M., the hour of the funeral services.

Mr. Voorhees was elected a Member of the American Society of Civil Engineers on May 6th, 1885. He served as a Director in 1890.

FRANS ENGSTRÖM, Assoc. M. Am. Soc. C. E.*

Died March 20th, 1916.

Frans Engström, the son of Ludwig and Frederika Engström, was born in Stockholm, Sweden, on November 28th, 1851. He was educated in his native city and was graduated from the Latin College and the Royal Polytechnical High School.

After his graduation, Mr. Engström was engaged, for two years, in an architect's office on private surveys, and also as Assistant Resident Engineer on the construction of the Government Railway of Sweden.

In 1881, he came to the United States and settled in Pittsburgh, Pa., where he was engaged with the Pennsylvania Railroad Company, as Draftsman, Chief Draftsman, and Assistant Engineer, until 1895. During this time, he designed and superintended the construction of the Penn Street Freight Station in Pittsburgh, and made plans and specifications for extensive dock construction at Erie, Pa., and at Ashtabula and Cleveland, Ohio. He also made the plans and specifications for all heavy bridge masonry and retaining walls on the Company's lines and for elevating its tracks through Pittsburgh and Allegheny.

In 1895, Mr. Engström was appointed Assistant to the Director of Public Works of the City of Pittsburgh, which position he resigned in 1899. While serving in this capacity, he built the large twin reservoirs at Highland Park, for the Pittsburgh water supply.

* Memoir prepared by the Secretary, from information on file at the Society House.

During 1899 and 1900, he was engaged in private practice as Civil and Hydraulic Engineer, with an office in Pittsburgh. In 1901, Mr. Engström was appointed Civil Engineer with the Carnegie Steel Company, retaining that position until 1903, when he entered the service of James Stewart and Company as Engineer of Inspection.

In 1905, Mr. Engström went to the American Bridge Company, at Ambridge, Pa., where he remained, as Engineer, until March, 1907. In April, 1907, he removed to Altoona, Pa., where he had been appointed City Engineer, retaining that office until 1915. As City Engineer Mr. Engström had charge of extensive paving work, supervised the planning of the East Altoona disposal plant, built the Seventh Street Bridge, and had charge of other important municipal improvements.

In 1915, Mr. Engström returned to Pittsburgh, but his health having failed, he was not able to engage actively in his profession. He had only been discharged from the hospital where he had been undergoing treatment for five months, when his sudden death from heart failure occurred on March 20th, 1916.

Mr. Engström was a talented and highly educated man. He spoke seven languages, and, being a great reader, was well informed, not only regarding his Profession, but on all subjects of general interest. Among his professional friends, he was considered one of the best estimating engineers in Pennsylvania.

On August 25th, 1884, Mr. Engström was married to Miss Bertha Lindstrum, who, with four children, survives him.

He was a member of the Engineers' Society of Western Pennsylvania, Duquesne Commandery No. 72, Knights Templar, and Syria Temple of Shriners, of Pittsburgh, and of Altoona Lodge No. 102, Benevolent Protective Order of Elks.

Mr. Engström was elected an Associate Member of the American Society of Civil Engineers on May 4th, 1892.

PHILIP HENRY PARTHESIUS, Assoc. M. Am. Soc. C. E.*

DIED FEBRUARY 15TH, 1916.

Philip Henry Parthesius, the eldest son of Dorathea Jordan and Julius Parthesius, was born at Troy, N. Y., on December 15th, 1881. He received his early education in the public schools of Troy and, later, attended the Rensselaer Polytechnic Institute, from which he was graduated with high honors in 1904, receiving the degree of Civil Engineer.

* Memoir prepared by H. O. Schermerhorn, Assoc. M. Am. Soc. C. E., Troy, N. Y.

Mr. Parthesius began his professional work in the Bridge and Construction Department of the Pennsylvania Steel Company, at Steelton, Pa., remaining there about a year. On leaving this work, he became Assistant Engineer on the construction of a large extension to the water-works system of Troy, N. Y. In this capacity, he was engaged in the building of storage reservoirs, pipe lines, dams, controlling works, etc. On the completion of this work which took about 3 years, Mr. Parthesius became connected with the New York State Civil Service Commission at Albany, in the capacity of Engineering Examiner, and, in October, 1913, he was made Assistant Chief Examiner of this Commission.

While with the Civil Service Commission, he had much to do with the preparation and rating of examinations for engineering positions in all State Departments, including those of the State Engineer and Surveyor, Public Service Commission, and the Highway Department, all of which required a large number of men to handle the extensive work on the Barge Canal, New York City subways, and the improved highway systems.

Mr. Parthesius was a wide reader and a keen student; a man of calm, even temperament, a true friend and gentleman, who possessed the confidence and respect of those who had the pleasure of his acquaintance. His early demise removed from the Profession one who was deeply devoted to his work, and who was just entering the pathway leading to a successful career in engineering work. His sudden illness and death was deeply lamented by a wide circle of friends and associates. He died on February 15th, 1916, after a brief illness.

Mr. Parthesius was unmarried, and is survived by his mother and one brother, Henry J. Parthesius, also a civil engineer.

He was a member of the Albany Society of Civil Engineers and of the Eastern Society of Civil Engineers.

Mr. Parthesius was elected an Associate Member of the American Society of Civil Engineers on November 1st, 1910.

WILLIAM THOMAS SHAW, Assoc. M. Am. Soc. C. E.*

Died February 26th, 1916.

William Thomas Shaw, a son of Ebenezer A. and Betsey S. (Dunham) Shaw, was born in Middleborough, Mass., on May 6th, 1880. His father was a veteran of the Civil War.

From the local schools, Mr. Shaw went to Dartmouth College where, as at home, he was a renowned exponent of the National game, filling the positions of pitcher and first baseman on the 'Varsity nine. He was

* Memoir prepared by F. S. Weston, Assoc M. Am. Soc. C. E.

a member of the Phi Delta Theta fraternity, and of the Senior Society, Casque and Gauntlet.

After receiving the degree of B. S., in 1904, he entered the Thayer School of Civil Engineering, an associated school at Hanover, N. H., founded in 1871 by Gen. Sylvanus Thayer, father of the United States Military Academy. There he was well grounded in the fundamentals of Civil Engineering, under the directorship of that able and scholarly professor, Robert Fletcher, M. Am. Soc. C. E. Mr. Shaw rounded out his education by spending the summer and fall of 1904 in surveying; the spring of 1905 as Aide on the Forestry Survey of Dartmouth College Grant, Coos County, New Hampshire; and from June to November, 1905, as Instrumentman on electric railway construction at Sterling, Mass.

Receiving the degree of C. E., in 1906, Mr. Shaw was, for a short time, in the field office of the Charles River Basin Commission, as Computer. In November, 1906, he went to Pennsylvania, where he was employed by the Cumberland Valley Railroad for two months as Assistant to Crosby Tappan, Construction Engineer. He was then put in charge of 6 miles of revision work to eliminate grade crossings, reduce grades, and double-track.

On May 5th, 1909, Mr. Shaw entered the service of the Boston Elevated Railway Company, under the late George A. Kimball, M. Am. Soc. C. E., Chief Engineer. He was employed in the Cambridge Office of the Bureau of Elevated and Subway Construction, first as Computer and Checker, and, later, as Assistant Engineer during the construction of the Main Street Subway. In the latter position, Mr. Shaw was engaged on the design and plans of the Eliot Square Car-House, Cambridge, including foundations, floor, retaining walls, and track layout. The Car-House is the Cambridge Terminal of the Cambridge Subway, and consists of a large area of storage tracks, both covered and in the open, repair shops, etc., for the large cars used in the Subway.

Mr. Shaw was rapidly advancing in his chosen field when, on July 18th, 1911, just as he was about to sign the plans which he had been preparing, he was forced to resign on account of pulmonary tuberculosis. After seeking to regain his health in various places, he returned to Middleborough, Mass., and built a home adjacent to the place of his birth, where he continued to make a brave, but losing, fight against the ravages of the disease, by working in the open air.

He was a clean young man, ambitious, conscientious, with a strong sense of duty and loyalty; of excellent judgment and clear and orderly way of thinking. He had that happy faculty of making friends wherever he went and also retaining them. To the last, he was hopeful and cheerful, laying his plans for the future and ever ready to help others.

On June 30th, 1910, Mr. Shaw was married to Madeleine R., daughter of William Scott and Mary (Bryant) Fleming, of Greencastle, Pa., who survives him.

He was a member of the Boston Society of Civil Engineers and the Thayer Society of Engineers. He was also a member of the First Congregational Church, the Masons, and the Sons of Veterans.

Mr. Shaw was elected an Associate Member of the American Society of Civil Engineers on June 30th, 1910.

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"The Yale Bowl." CHARLES A. FERRY......................................Oct., "

PAPERS IN THIS NUMBER

"THE VALUATION OF LAND." L. P. JERRARD. (To be presented Dec. 20th, 1916.)

PAPERS AND DISCUSSIONS CURRENT IN PROCEEDINGS

PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

VOL. XLII—No. 10

AMERICAN SOCIETY OF CIVIL ENGINEERS FOUNDED 1852

December, 1916

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PROCEEDINGS

OF THE

AMERICAN SOCIETY

OF

CIVIL ENGINEERS

(INSTITUTED 1852)

VOL. XLII—No. 10

DECEMBER, 1916

Edited by the Secretary, under the direction of the Committee on Publications.

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NEW YORK 1916

Vol. XLII. DECEMBER, 1916. No. 10.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PROCEEDINGS

This Society is not responsible for any statement made or opinion expressed in its publications.

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MINUTES OF MEETINGS

OF THE SOCIETY

November 15th, 1916.—The meeting was called to order at 8.30 P. M.; Director Arthur S. Tuttle in the chair; Chas. Warren Hunt, Secretary; and present, also, 148 members and 15 guests.

A paper by Charles A. Ferry, M. Am. Soc. C. E., entitled "The Yale Bowl", was presented by the author and illustrated with lantern slides. The paper was discussed by Thomas C. Atwood, M. Am. Soc. C. E., who illustrated his remarks with lantern slides. The subject was discussed further by Messrs. James B. French, Herbert C. Keith, John F. O'Rourke, and T. Kennard Thomson.

The Secretary announced the following deaths:

Sidney Willett Hoag, Jr., of New York City, elected Member, September 2d, 1885; died November 1st, 1916.

William Cooper Cuntz, of New York City, elected Associate, September 6th, 1910; died November 2d, 1916.

Adjourned.

December 6th, 1916.—The meeting was called to order at 8.30 P. M.; S. C. Thompson, M. Am. Soc. C. E., in the chair; Chas. Warren Hunt, Secretary; and present, also, 167 members and 19 guests.

The minutes of the meetings of October 18th and November 1st, 1916, were approved as printed in *Proceedings* for November, 1916.

Walter E. Spear, M. Am. Soc. C. E., gave an informal talk descriptive of the Narrows Siphon of the Catskill Aqueduct, illustrating his remarks with lantern slides. The subject was discussed informally by Messrs. J. P. Hogan, A. D. Flinn, E. Wegmann, W. J. Boucher, F. T. Llewellyn, T. C. Atwood, and others.

The Secretary announced the election of the following candidates on November 28th, 1916:

As Members

Pierre Edmond Amiot, Chicoutimi, Que., Canada
Herbert Howard Bassett, Groton, N. Y.
Montgomery Babcock Case, Memphis, Tenn.
Gano Dunn, New York City
Fred Keating Hilt, Ridgewood, N. J.
Arthur Montzheimer, Joliet, Ill.
Almos Davidson Neeld, Pittsburgh, Pa.
George Edward Poucher, Ambridge, Pa.
Herbert Spencer Ripley, Worth, Ill.
Norman Leslie Stamm, Philadelphia, Pa.
William Thomas Taylor, London, England
Fenwick Milford Thebo, Phœnix, Idaho
Robert Lyle Totten, Birmingham, Ala.
William Archie Weldin, Pittsburgh, Pa.
Alfred Rutgers Whitney, Jr., New York City
George Brown Zahniser, New Castle, Pa.

As Associate Members

Raymond Glime Alexander, St. Louis, Mo.
Lucius Ephraim Allen, Belleville, Ont., Canada
Bradley White Bartholomew, Palmer, Mass.
Harry Newton Benkert, Philadelphia, Pa.
Charles Roberts Bennett, Manila, Philippine Islands
Harry Bennett, Brainerd, Minn.

Walter Glen Black, Mandan, N. Dak.
Clarence Edwin Boesch, El Paso, Tex.
Albert George Bowers, Lancaster, Pa.
John Everett Bowersmith, Oakland, Cal.
Milford Edward Chappel, Swan Quarter, N. C.
Frank Willard Cherrington, Toledo, Ohio
William Clarkson, Jr., Corsicana, Tex.
Calvin Earnest Cock, Honey Grove, Tex.
Charles Ivan Day, Jacksonville, Fla.
Charles Francis Dingman, Palmer, Mass.
Aymar Embury, 2d, New York City
Frank Hamilton Finch, Dormont, Pa.
George Stedman Frank, Medford, Mass.
Neil McAdory Gamble, New Orleans, La.
Sidney Howard George, Harbona, Idaho
Walter Edward Giesen, Dallas, Tex.
Asa Waters Grosvenor, Fort Wayne, Ind.
Richard Harvey Jamison, Alameda, Cal.
Royce Daniel King, Gadsden, Ala.
Henri Louis Lambert, Bocas del Toro, Panama
Arthur Carl Lee, Charlotte, N. C.
David Lessing Leffert, Algona, Iowa
Frank Gardner Legg, Jr., Lansing, Mich.
John Francis Lynch, West Haven, Conn.
Lester Chipman McCandliss, Pittsburgh, Pa.
Charles Andrew McCollough, South Bethlehem, Pa.
John Crane McVea, Houston, Tex.
Lora Walter Miller, Chicago, Ill.
Arthur Knox Mitchell, Victoria, B. C., Canada
James Powell Murray, Austin, Tex.
Ernest Lindley Myers, Dallas, Tex.
Claude Henry Rightmire, Stuart, Fla.
Ralph Earle Rohn, Canton, Ohio
Earl Douglas Rutherford, Chicago, Ill.
Van Rensselaer Powell Saxe, Baltimore, Md.
Harold Arthur Sewell, Newport, Wash.
Ernest Alton Shafer, Olympia, Wash.
Hobart Doane Shaw, Gulfport, Miss.
Searcy Bradfield Slack, Athens, Ga.
John Wilson Toyne, South Bend, Ind.
James Irwin Tucker, Norman, Okla.
Charles Emmett Washburn, Los Angeles, Cal.
George Thompson Willard, Chicago, Ill.
Walter Edward Winn, Helena, Ark.
William Daugherty Wrightson, Washington, D. C.

As Associates

Arthur Samuel Bent, Los Angeles, Cal.
George Copp Warren, Boston, Mass.

As Juniors

Charles Joseph Boland, Troy, N. Y.
Raymond Fielding Braly, San Pedro, Cal.
Kee Ham Chin, Seattle, Wash.
Clarence Dexter Conway, Los Molinos, Cal.
Carl Henry Cotter, Mt. Vernon, Ohio
Ernest Charles Dedicke, McAllen, Tex.
Samuel DeMoss, Spokane, Wash.
Ralph Burrows Everett, Alcoa, Tenn.
Abraham Manuel Fox, Detroit, Mich.
Frank Edward Kohl, Jr., New York City
James Taylor Landreth, Scarsdale, N. Y.
Valentine Brousseau Libbey, Providence, R. I.
Joseph Eugene Love, Chicago, Ill.
Victor John Milkowski, Baldwinsville, N. Y.
Rufus Burleson Pearce, Madison, Wis.
John Sanford Peck, Albany, N. Y.
Arthur Edward Prack, Pittsburgh, Pa.
Glenn Stanton Reeves, Harrisburg, Pa.
Ralph Whitney Reynolds, Berkeley, Cal.
Lester Cushing Rogers, Glacier, B. C., Canada
Daniel Norman Turner, Loretto, Pa.
William Edward Whalen, Toledo, Ohio
David Ewing White, Louisville, Ky.

The Secretary announced the transfer of the following candidates on November 28th, 1916:

From Associate Member to Member

James Henry Millar Andrews, Philadelphia, Pa.
James Hervey Dingle, Charleston, S. C.
Lewis Merritt Gram, Ann Arbor, Mich.
Herbert Frank Howe, Boston, Mass.
Walter Clark Howe, San Luis Obispo, Cal.
Don Alexander MacCrea, Little Rock, Ark.
Clifford Bennett Moore, Long Island City, N. Y.
Harold Lyell Stevens, Chicago, Ill.
Thomas Johnson Strickler, Topeka, Kans.

From Junior to Associate Member

Murray James Backus, Punta Alegre, Cuba
Robert Crewdson Benson, Werribee, Victoria, Australia
Ross Judson Buck, Lafayette, Ind.
Walter Van Buck, Newton, Kans.
Carl Crandall, Ithaca, N. Y.
John Waggoner Currey, Wagoner, Okla.
Allen Stewart Davison, Pittsburgh, Pa.
Frank Haskell Densler, Albany, N. Y.
Russell Burns Easton, Aberdeen, S. Dak.
Raymond Arden Edwards, San Francisco, Cal.
John Frederick William Gebhardt, Asuncion, Paraguay
John Carl Gotwals, Washington Barracks, D. C.
Charles Haydock, Philadelphia, Pa.
George Norbert Kelley, Kansas City, Mo.
Livingston Allaire Leeds, New York City
Harold MacLean Lewis, Loretto, Pa.
Clifford Lynde, Brooklyn, N. Y.
Quinces Robertus Nolan, La Grange, Ga.
Erich Moore Plump, Jefferson City, Mo.
Edward Burchard Sandelands, Galveston, Tex.
Henry Lawrence Thackwell, Marbleton, Wyo.
Fred Morton Thomson, El Paso, Tex.
James Wilmot, New York City

The Secretary announced the following deaths:

William Henry Jaques, of Little Boar's Head, N. H., elected Member, July 2d, 1890; date of death unknown.

Louis Henry Rathmann, of Buffalo, N. Y., elected Member, May 2d, 1911; died November 17th, 1916.

Robert Maitland Roy, of Hamilton, Ont., Canada, elected Associate Member, October 3d, 1900; Member March 5th, 1907; died June 27th, 1916.

Frank Oscar Sinclair, of Burlington, Vt., elected Member, November 6th, 1901; died November 15th, 1916.

José Petronio Katigbak, of Manila, Philippine Islands, elected Associate Member, April 1st, 1914; died May 16th, 1916.

Charles Wilson Ross, of Newton Center, Mass., elected Associate, February 28th, 1911; died April 11th, 1916.

Adjourned.

December 20th, 1916.—Because of the necessity of going to press with this number of *Proceedings* in advance of this meeting, the publication of its minutes must be deferred until January, 1917.

OF THE BOARD OF DIRECTION

(Abstract)

November 28th, 1916.—The Board met immediately upon the adjournment of the Membership Committee; Director Fuller in the chair; Chas. Warren Hunt, Secretary; and present, also, Messrs. Davies, Endicott, Humphreys, and Tuttle.

Ballots for Membership were canvassed, resulting in the election of 16 Members, 51 Associate Members, 2 Associates, and 23 Juniors, and the transfer of 23 Juniors to the grade of Associate Member.

Nine Associate Members were transferred to the grade of Member.

A report from the Membership Committee was received and acted upon.

Adjourned.

ANNOUNCEMENTS

The House of the Society is open from 9 A. M. to 10 P. M., every day, except Sundays, Fourth of July, Thanksgiving Day, and Christmas Day.

FUTURE MEETINGS

January 3d, 1917.—8.30 P. M.—A regular business meeting will be held, and a paper by R. E. Bakenhus, M. Am. Soc. C. E., entitled "Tests of Concrete Specimens in Sea Water, at Boston Navy Yard", will be presented for discussion.

This paper is printed in this number of *Proceedings*.

ANNUAL MEETING

The Sixty-fourth Annual Meeting will be held at the Society House, on Wednesday and Thursday, January 17th and 18th, 1917.

COMMITTEE OF ARRANGEMENTS

GEORGE H. CLARK,

C. V. V. POWERS,	CHARLES E. TROUT,
JAMES F. SANBORN,	CHARLES WARREN HUNT.

The Business Meeting will be called to order at 10 o'clock on Wednesday morning. The Annual Reports will be presented, Officers for the ensuing year elected, members of the Nominating Committee appointed, Reports of Special Committees presented for discussion, and other business transacted.

SPECIAL MEETINGS

Meetings for the discussion of the Progress Report of the Special Committee on Materials for Road Construction, will be held at the Society House, at 10 A. M. and 2 P. M. on Friday, January 19th, 1917 (the day following the close of the Annual Meeting of the Society).

REPORTS OF SPECIAL COMMITTEES

Reports of the Special Committees to Investigate Conditions of Employment of, and Compensation of, Civil Engineers, on Materials for Road Construction, on Steel Columns and Struts, on Concrete and Reinforced Concrete, on Valuation of Public Utilities, and on A National Water Law, are printed in this number of *Proceedings* with the Papers and Discussions.

SEARCHES IN THE LIBRARY

In January, 1902, the Secretary was authorized to make searches in the Library, upon request, and to charge therefor the actual cost to the Society for the extra work required. Since that time many searches have been made, and bibliographies and other information on special subjects furnished.

The resulting satisfaction, to the members who have made use of the resources of the Society in this manner, has been expressed frequently, and leaves little doubt that if it were generally known to the membership that such work would be undertaken, many would avail themselves of it.

The cost is trifling compared with the value of the time of an engineer who looks up such matters himself, and the work can be performed quite as well, and much more quickly, by persons familiar with the Library.

In asking that such work be undertaken, members should specify clearly the subject to be covered, and whether references to general books only are desired, or whether a complete bibliography, involving search through periodical literature, is desired.

It sometimes happens that references are found which are not readily accessible to the person for whom the search is made. In that case the material may be reproduced by photography, and this can be done for members at the cost of the work to the Society, which is small. This method is particularly useful when there are drawings or figures in the text, which would be very expensive to reproduce by hand.

PAPERS AND DISCUSSIONS

Members and others who take part in the oral discussions of the papers presented are urged to revise their remarks promptly. Written communications from those who cannot attend the meetings should be sent in at the earliest possible date after the issue of a paper in *Proceedings*.

All papers accepted by the Publication Committee are classified by the Committee with respect to their availability for discussion at meetings.

Papers which, from their general nature, appear to be of a character suitable for oral discussion, will be published as heretofore in *Proceedings,* and set down for presentation to a future meeting of the Society, and on these, oral discussions, as well as written communications, will be solicited.

All papers which do not come under this heading, that is to say, those which, from their mathematical or technical nature, in the opinion of the Committee, are not adapted to oral discussion, will not be scheduled for presentation to any meeting. Such papers will be published in *Proceedings* in the same manner as those which are to be presented at meetings, but written discussions only will be requested for subsequent publication in *Proceedings* and with the paper in the volumes of *Transactions*.

The Board of Direction has adopted rules for the preparation and presentation of papers, which will be found on page 429 of the August, 1913, *Proceedings*.

LOCAL ASSOCIATIONS OF MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

San Francisco Association, Organized 1905.

President, H. L. Haehl; Secretary, E. T. Thurston, 57 Post Street, San Francisco, Cal.

The San Francisco Association of Members of the American Society of Civil Engineers holds regular bi-monthly meetings, with banquet, and weekly informal luncheons. The former are held at 6 P. M., at the Palace Hotel, on the third Tuesday of February, April, June, August, and October, and the third Friday of December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M., every Wednesday, and the place of meeting may be ascertained by communicating with the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in San Francisco, and any such member will be gladly welcomed as a guest.

(Abstract of Minutes of Meeting)

October 17th, 1916.—The meeting was called to order at the Palace Hotel; Vice-President Couchot in the chair; E. T. Thurston, Secretary; and present, also, 83 members and guests.

The Entertainment Committee showed moving pictures illustrating a trip through Glacier National Park and the work of the United States Reclamation Service.

Messrs. T. J. Allan, C. E. Beugler, and Berthold Wuth were appointed on the Entertainment Committee for the December meeting.

Communications were read from the Philadelphia Association relative to the publication of papers presented before the San Francisco Association, provided they are not to be presented before the Society, and also from the Building Trades Employers Association of San Francisco enclosing a report on a proposed bridge between Oakland and San Francisco. The attention of the Association was also called to the circular issued by the Committee to expedite the completion of the topographic map of the United States.

Mr. W. L. Huber, for the Committee appointed to consider the suggestions for the advancement of the Association, contained in the Inaugural Address of President Haehl, reported that the work of the Committee was still held in abeyance, in view of the proposed revision of the Constitution of the Society.

Mr. J. D. Galloway, for the Joint Committee on Military Affairs, called attention to the circular issued by the Consulting Board of the National Engineering Societies, and announced that the Committee had received notice that, in case a class of engineers was formed in this city, every assistance would be given by the War Department. He also announced that the Committee would soon issue a circular explanatory of the movement, and would provide facilities for assistance to those who desired to take up the prescribed courses of study.

The attention of the Association was called to the fact that as yet the Schulze Prize for Juniors had produced no results and members

of the Association were urged to arouse the interest of Juniors in this matter.

Mr. T. J. Allan outlined the situation involving the dismissal of Mr. W. N. Frickstad, as Assistant Superintendent of Streets of Oakland, Cal., his views on the subject being endorsed by Mr. P. F. Brown, Superintendent of Streets. After discussion, on motion, duly seconded. President Haehl was directed to appoint a committee of three to investigate the facts of the case and report at the next meeting, in order that the Association may lend its moral and financial aid in the matter. The Chair subsequently appointed as such Committee, Messrs. Charles D. Marx, T. J. Allan and A. H. Markwart.

Relative to the matter of suggestions for member of the Nominating Committee, the Secretary announced that the name of Mr. W. C. Hammatt had been submitted to him as one who would be willing to represent this District as a member of the Nominating Committee.

On motion, duly seconded, the President was directed to appoint a committee of five to investigate the methods and conditions of employment of engineers by State and municipal governments, and later the personnel of this Committee was announced, as follows: Messrs. M. M. O'Shaughnessy, Chairman, R. A. Thompson, Jerome Newman, Franklin Riffle, and L. S. Griswold.

A paper entitled the "Calaveras Hydraulic-Fill Earth Dam", the design and construction of which was illustrated by stereopticon views was presented by Mr. George A. Elliot. After a brief discussion, on motion, duly seconded, the paper was ordered printed for distribution to the membership.

Adjourned.

On Saturday, October 21st, 1916, 57 members and guests of the Association inspected the Calaveras Dam, as guests of the Spring Valley Water Company, under the personal direction of Messrs. Elliot and Espy.

Colorado Association, Organized 1908.

President, Thomas W. Jaycox; Secretary-Treasurer, L. R. Hinman, 1400 West Colfax Avenue, Denver, Colo.

The meetings of the Colorado Association of Members of the American Society of Civil Engineers (Denver, Colo.) are held on the second Saturday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary. The meetings are usually preceded by an informal dinner. Members of the American Society of Civil Engineers will be welcomed at these meetings.

Weekly luncheons are held on Wednesdays at 12.30 P. M., at Daniel's and Fisher's.

Visiting members are urged to attend the meetings and luncheons.

(Abstract of Minutes of Meetings)

September 9th, 1916.—The meeting was called to order at the Denver Athletic Club; President Jaycox in the chair; L. R. Hinman, Secretary; and present, also, 15 members and 4 guests.

The minutes of the meeting of June 10th, 1916, were read and approved.

Mr. W. B. Freeman addressed the meeting on "Observations in Siam", illustrating his remarks with about 100 lantern slides.

A vote of thanks was tendered Mr. Freeman for his interesting and instructive address.

Adjourned.

October 7th, 1916.—The meeting was called to order at the Denver Athletic Club; Vice-President Follansbee in the chair; L. R. Hinman, Secretary; and present, also, 85 members and guests.

This meeting was held as a joint meeting of the Association, the Denver Section of the American Institute of Electrical Engineers, and the local members of the American Society of Mechanical Engineers, and all business was omitted.

Mr. Q. W. Hershey, of the Heavy Traction Division, Westinghouse Electric and Manufacturing Company, addressed the meeting in explanation of motion pictures illustrating his subject, "Westinghouse Steam Railroad Electrifications." Installations on several Eastern roads were shown and described, and the subject was discussed informally.

Mr. Sam G. Porter, Secretary, Calgary Branch, Canadian Society of Civil Engineers, and Assistant Chief Engineer, Irrigation Branch, Department of the Interior of Canada, presented a paper on "Irrigation Development in Western Canada", illustrating his remarks with lantern slides.

A vote of thanks was extended to Mr. Hershey and to Mr. E. C. Means, Denver Manager of the Railway and Lighting Department of the Westinghouse Company, for the interesting pictures and discussion, and to Mr. Porter for his interesting address.

Adjourned.

Atlanta Association, Organized 1912.

President, Paul H. Norcross; Secretary-Treasurer, Thomas P. Branch, Georgia School of Technology, Atlanta, Ga.

The Association holds its meetings at the University Club, Atlanta, Ga. Regular monthly luncheon meetings are held to which visiting members of the Society are always welcome.

Baltimore Association, Organized 1914.

President, H. D. Bush; Secretary-Treasurer, Charles J. Tilden, The Johns Hopkins University, Baltimore, Md.

Cleveland Association, Organized 1914.

President, Robert Hoffmann; Secretary-Treasurer, George H. Tinker, Hickox Building, Cleveland, Ohio.

(Abstract of Minutes of Meeting)

October 14th, 1916.—The meeting was called to order at 12 M., at the rooms of the Cleveland Engineering Society; President Robert Hoffmann in the chair; George H. Tinker, Secretary; and present, also, 17 members.

A resolution was passed recommending the election of Mr. A. J. Himes for Member of the Nominating Committee from District No. 6.

The Secretary was instructed to communicate with the Board of Direction, requesting the placing of duplicate volumes from the Library of the Society in the library of the Cleveland Engineering Society.

Mr. Himes called attention to the forthcoming special publication of the Cleveland Engineering Society, and requested the co-operation of the members.

Mr. W. J. Watson presented the greetings of the San Francisco Association.

Adjourned.

Detroit Association, Organized 1916.

The regular meetings of the Association are held on the second Friday of December, April, and October, the last being the Annual Meeting.

District of Columbia Association, Organized 1916.

President, A. P. Davis; Secretary-Treasurer, John C. Hoyt, U. S. Geological Survey, Washington, D. C.

Illinois Association, Organized 1916.

President, Onward Bates; Secretary-Treasurer, E. N. Layfield, 4251 Vincennes Avenue, Chicago, Ill.

The regular meetings of the Association are held on the second Monday of March, June, September, and December, the last being the Annual Meeting. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Louisiana Association, Organized 1914.

President, W. B. Gregory; Secretary, Charles W. Okey, Tulane University, New Orleans, La.

The regular meetings of the Association are held at The Cabildo, New Orleans, La., on the first Monday of January, April, July, and October.

Northwestern Association, Organized 1914.

President, George L. Wilson; Secretary, Ralph D. Thomas, 508 South First Street, Minneapolis, Minn.

(Abstract of Minutes of Meeting)

November 28th, 1916.—The meeting was called to order at the Minneapolis Athletic Club; President George L. Wilson in the chair; Ralph D. Thomas, Secretary; and present, also, 41 members and guests.

The minutes of the last meeting were read and approved.

Resolutions on the death of Vice-President Leonard W. Rundlett were presented by the Secretary, and adopted unanimously.

The report of the Committee, consisting of Messrs. Wolff, King, and Armstrong, appointed to investigate the insinuations, as published in the *Fairmont-Sentinel*, concerning the State Highway Commission and a highway bridge at Fairmont, Minn., was accepted, and the Committee was discharged.

After prolonged discussion as to the fitness and advisability of the Association participating in questions of public matters, political and otherwise, it was moved and seconded that the President appoint a committee of three to investigate the powers of the Association and report on a plan which will enable it to promote the interests of the Engineering Profession more effectively.

Messrs. Darling, Wolff, and Claussen were subsequently appointed as such committee.

Capt. J. B. Woolnough, U. S. A., addressed the meeting on his experience as an officer at a Citizens' Summer Training Camp.

Lieut.-Col. E. H. Schulz, Corps of Engineers, U. S. A., discussed at length the Engineers' Reserve Corps of the U. S. Army and explained how appointments were made.

Adjourned.

Philadelphia Association, Organized 1913.

President, Samuel T. Wagner; Secretary, C. W. Thorn, 1313 South Broad Street, Philadelphia, Pa.

The regular meetings of the Association are held at the Engineers' Club of Philadelphia, 1317 Spruce Street, on the first Monday in January, April, and October, the last being the Annual Meeting.

Portland, Ore., Association, Organized 1913.

President, J. P. Newell; Secretary, J. A. Currey, 194 North 13th Street, Portland, Ore.

St. Louis Association, Organized 1914.

President, J. A. Ockerson; Secretary-Treasurer, Gurdon G. Black, 34 East Grand Avenue, St. Louis, Mo.

The meetings of the Association are held at the Engineers' Club Auditorium. The Annual Meeting is held on the fourth Monday in November. The time of other meetings is not fixed, but this information will be furnished on application to the Secretary.

(Abstract of Minutes of Meeting)

November 27th, 1916.—The Annual Meeting was called to order at the American Annex Hotel; President J. A. Ockerson in the chair; Gurdon G. Black, Secretary.

The officers of the Association were re-elected for another year, as follows: President, John A. Ockerson; Vice-Presidents, Edward E. Wall and Frank G. Jonah; and Secretary-Treasurer, Gurdon G. Black.

Informal addresses were made by Mr. Baxter L. Brown, on "His Early Experiences as an Engineer"; Mr. Henri Rusch, on "His Mining Experiences in South Africa"; Mr. S. L. Wonson, on "Bridge Building in South America"; Mr. J. L. Van Ornum, on "Investigations Made by the Carnegie Foundation as to the Educational Qualifications of an Engineer"; and Mr. C. M. Talbert, on "His Early Experiences on the Missouri and Mississippi Rivers."

It was decided to hold the next meeting of the Association on January 8th, 1917.

Adjourned.

San Diego Association, Organized 1915.

President, N. B. Kellogg; Secretary-Treasurer, J. R. Comly, 4105 Falcon Street, San Diego, Cal.

Seattle Association, Organized 1913.

President, A. O. Powell; Secretary-Treasurer, Carl H. Reeves, 444 Henry Building, Seattle, Wash.

The regular meetings of the Association are held at 12.15 P. M., on the last Monday of each month, at The Arctic Club.

(Abstract of Minutes of Meetings)

October 30th, 1916.—The meeting was called to order at 12.15 P. M., at the Arctic Club; President Powell in the chair; Carl H. Reeves, Secretary; and present, also, 18 members and guests.

The minutes of the meeting of September 25th, 1916, were read and approved.

The resignation of Mr. J. R. West as a member of the Association was read and accepted.

A letter from the Philadelphia Association in reference to the publication of papers presented before the Association, in the *Bulletin* of the Engineers' Club of Philadelphia, was read.

The Secretary read an invitation extended to the Association and its members to visit the new physical testing laboratory of the Bogardus Testing Laboratories.

A letter from the State Commissioner of Health, enclosing a copy of a bill for the regulation and control of water supplies and sewage, was referred to the Legislative Committee.

On motion, duly seconded, the report of the Preliminary Joint Council of the Associated Engineering Societies, was adopted, and Messrs. John L. Hall and Robert Howes were continued as Permanent Councillors of the Association for the current year.

The Secretary then read the report of the Special Committee on the State Water Code. On motion, duly seconded, Mr. T. A. Noble was allowed to withdraw his name from the report as submitted and to present a letter from himself to Mr. Carrol B. Graves as a Minority Report. After discussion by Messrs. Dimock, Hussey, Jacobs, McMorris, Allison, Fuller, and Powell, it was decided, on motion, duly seconded, to reject the report of the Committee as submitted, and that a meeting of the Association for the purpose of considering further the Committee's recommendations, be called at 8 P. M., on Wednesday, November 1st, 1916.

Adjourned.

November 1st, 1916.—In accordance with the action of the meeting of the Association on October 30th, 1916, for further consideration of the recommendations of the State Water Code Committee, the meeting was called to order at 8 P. M., in the Assembly Room of the Seattle Chamber of Commerce; President Powell in the chair; Carl H. Reeves, Secretary; and present also 14 members and guests.

A point of order as to the validity of the motion to reject the report of the Water Code Committee, passed at the meeting of October

30th, 1916, having been raised, on motion, duly seconded, the decision of the Chair that such motion was in order, was sustained.

On motion, duly seconded, it was decided to reconsider the motion to reject the Committee's report, and, after a motion to amend and adopt such report had been lost, the President stated that he would consider that the Committee's recommendations were before the meeting for adoption or rejection separately.

After discussion, on motion, duly seconded, the report, with certain amendments, was adopted.

The Majority Report of the Special Committee on The Relations Between the American Society of Civil Engineers and Its Local Sections and Between Local Sections and Other Engineering Societies or Clubs, was presented, with a Minority Report signed by Mr. A. H. Fuller, asking that provision be made for Student Chapters at Engineering Colleges, and, on motion, duly seconded, the Majority Report was adopted, the motion to include the Minority Report having been lost.

Adjourned.

November 27th, 1916.—The meeting was called to order at 12.15 P. M., at the Arctic Club; President A. O. Powell in the chair; Carl H. Reeves, Secretary; and present, also, 12 members and guests.

The minutes of the meeting of October 30th, 1916, and of the adjourned meeting of November 1st, 1916, were read and approved.

A letter from Mr. Charles Warren Hunt, Secretary of the Society, relative to the report of the Special Committee of the Association on the relations of National Engineering Societies and Local Associations of their members, was read, and the Secretary was instructed to advise Mr. Hunt that the report was intended for the use of the Board of Direction and not for publication.

Relative to the report on the Water Pollution Bill, the Secretary, in the absence of Mr. H. L. Grey, Chairman of the Legislative Committee, reported that the Committee had referred various sections of the Bill to Sub-Committees for study and report, and that the Chairman desired further time to prepare his report.

Mr. John L. Hall, Temporary President of the Associated Engineering Societies of Seattle, announced that five of the six societies forming the affiliation had completed all matters necessary for permanent organization, and that a meeting would soon be called to effect such organization.

Mr. Joseph Jacobs presented an outline of the proceedings at the Water Code Conference, held at North Yakima, Wash., on November 15th, 1916.

On motion, duly seconded, the date of the December meeting of the Association was changed from December 25th, to December 18th. 1916.

The President having asked the members present to express their views relative to a bill for the Licensing of Engineers, the subject was discussed informally by Messrs. Jacobs, Reeves, Carver, Hall, Ryan, and Hawes, the general opinion being that such a bill would be desirable. On motion, duly seconded, the Secretary was instructed to ask the Legislative Committee to make special effort to report on the subject at the next meeting.

On motion, duly seconded, the Secretary was also instructed to request the Association of Engineering Societies of Seattle to take up the question of the Licensing of Engineers at the earliest opportunity.

Adjourned.

Southern California Association, Organized 1914.

President, William Mulholland; Secretary, W. K. Barnard, 1105 Central Building, Los Angeles, Cal.

The Southern California Association of Members of the American Society of Civil Engineers (Los Angeles, Cal.) holds regular bi-monthly meetings, with banquet, at Hotel Clark, on the second Wednesday of February, April, June, August, October, and December, the last being the Annual Meeting of the Association.

Informal luncheons are held at 12.15 P. M. every Wednesday, and the place of meeting may be ascertained from the Secretary.

The by-laws of the Association provide for the extension of hospitality to any member of the Society who may be temporarily in Los Angeles, and any such member will be gladly welcomed as a guest at any of the meetings or luncheons.

Spokane Association, Organized 1914.

President, E. G. Taber; Secretary, B. J. Garnett, City Hall, Spokane, Wash.

The regular meetings of the Association are held on the second Friday of each month, except July and August. The hour and place of meeting are not fixed, but this information will be furnished on application to the Secretary.

Visiting members are invited to attend the meetings and luncheons.

Texas Association, Organized 1913.

President, John B. Hawley; Secretary, J. F. Witts, Dallas, Tex.

Utah Association, Organized 1916.

President, E. C. La Rue; Secretary-Treasurer, H. S. Kleinschmidt, 306 Dooley Building, Salt Lake City, Utah.

MINUTES OF MEETINGS OF SPECIAL COMMITTEES TO REPORT UPON ENGINEERING SUBJECTS

Special Committee on Materials for Road Construction

November 4th, 1916.—The meeting was called to order at the House of the Society. Present, George W. Tillson (Chairman *pro tem.*), H. K. Bishop, A. W. Dean, Nelson P. Lewis, Charles J. Tilden, and A. H. Blanchard (Secretary).

The minutes of the meeting of October 21st, 1916, were read and approved.

On motion the section of the 1917 Report of the Committee, pertaining to Broken Stone Roads, was adopted, together with paragraphs which the Committee requested the Secretary to prepare.

The following sections of the 1917 Report were adopted: Cement-Concrete, with additions; Bituminous Concrete Pavements; Sheet-Asphalt Pavements; Brick Pavements; Stone Block Pavements; and Wood Block Pavements.

The Introduction and Conclusion to the Report, as prepared by the Secretary, were adopted.

On motion, the section of the 1917 Report on General Conclusions, was adopted.

On motion, the complete 1917 Report was adopted.

Special Committee on Steel Columns and Struts

November 13th, 1916.—The meeting was called to order at 8 P. M., at the House of the Society, Present, George H. Pegram (Chairman), C. W. Hudson, James H. Edwards, and Lewis D. Rights (Secretary). Dr. G. R. Olshausen, Engineer-Physicist of the U. S. Bureau of Standards, was also present.

The minutes of the meeting of October 2d, 1916, were approved as written.

In accordance with instructions, the Secretary presented typewritten copies of the proposed Progress Report. The report was read in detail, and additions and corrections were suggested by the members of the Committee. On motion, duly seconded, the Secretary was instructed to make the corrections, and forward the report to the Secretary of the Society for publication in the December number of *Proceedings*.

On motion, the Committee adjourned to meet at the call of the Chairman.

PRIVILEGES OF ENGINEERING SOCIETIES EXTENDED TO MEMBERS OF THE AMERICAN SOCIETY OF CIVIL ENGINEERS

Members of the American Society of Civil Engineers will be welcomed by the following Engineering Societies, both to the use of their Reading Rooms, and at all meetings:

American Institute of Electrical Engineers, 33 West Thirty-ninth Street, New York City.

American Institute of Mining Engineers, 29 West Thirty-ninth Street, New York City.

American Society of Mechanical Engineers, 29 West Thirty-ninth Street, New York City.

Architekten-Verein zu Berlin, Wilhelmstrasse 92, Berlin W. 66, Germany.

Associação dos Engenheiros Civis Portuguezes, Lisbon, Portugal.

Australasian Institute of Mining Engineers, Melbourne, Victoria, Australia.

Boston Society of Civil Engineers, 715 Tremont Temple, Boston, Mass.

Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.

Canadian Society of Civil Engineers, 176 Mansfield Street, Montreal, Que., Canada.

Civil Engineers' Society of St. Paul, St. Paul, Minn.

Cleveland Engineering Society, Chamber of Commerce Building, Cleveland, Ohio.

Cleveland Institute of Engineers, Middlesbrough, England.

Dansk Ingeniorforening, Amaliegade 38, Copenhagen, Denmark.

Detroit Engineering Society, 46 Grand River Avenue, West, Detroit, Mich.

Engineers and Architects Club of Louisville, 1412 Starks Building, Louisville, Ky.

Engineers' Club of Baltimore, 6 West Eager Street, Baltimore, Md.

Engineers' Club of Kansas City, E. B. Murray, Secretary, 920 Walnut Street, Kansas City, Mo.

Engineers' Club of Minneapolis, 17 South Sixth Street, Minneapolis, Minn.

Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.

Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.

Engineers' Club of Toronto, 96 King Street, West, Toronto, Ont., Canada.

Engineers' Club of Trenton, Trent Theatre Building, 12 North Warren Street, Trenton, N. J.

Engineers' Society of Northeastern Pennsylvania, 415 Washington Avenue, Scranton, Pa.

Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.

Engineers' Society of Western Pennsylvania, 2511 Oliver Building, Pittsburgh, Pa.

Institute of Marine Engineers, The Minories, Tower Hill, London, E., England.

Institution of Engineers of the River Plate, Calle 25 de Mayo 195, Buenos Aires, Argentine Republic.

Institution of Naval Architects, 5 Adelphi Terrace, London, W. C., England.

Junior Institution of Engineers, 39 Victoria Street, Westminster, S. W., London, England.

Koninklijk Instituut van Ingenieurs, The Hague, The Netherlands.

Louisiana Engineering Society, State Museum Building, Chartres and St. Ann Streets, New Orleans, La.

Memphis Engineers' Club, Memphis, Tenn.

Midland Institute of Mining, Civil and Mechanical Engineers, Sheffield, England.

Montana Society of Engineers, Butte, Mont.

North of England Institute of Mining and Mechanical Engineers, Newcastle-upon-Tyne, England.

Oesterreichischer Ingenieur- und Architekten-Verein, Eschenbachgasse 9, Vienna, Austria.

Oregon Society of Civil Engineers, Portland, Ore.

Pacific Northwest Society of Engineers, 312 Central Building, Seattle, Wash.

Rochester Engineering Society, Rochester, N. Y.

Sachsischer Ingenieur- und Architekten-Verein, Dresden, Germany.

Sociedad Colombiana de Ingenieros, Bogota, Colombia.

Sociedad de Ingenieros del Peru, Lima, Peru.

Societe des Ingenieurs Civils de France, 19 rue Blanche, Paris, France.

Society of Engineers, 17 Victoria Street, Westminster, S. W., London, England.

Svenska Teknologforeningen, Brunkebergstorg 18, Stockholm, Sweden.

Tekniske Forening, Vestre Boulevard 18-1, Copenhagen, Denmark.

Vermont Society of Engineers, George A. Reed, Secretary, Montpelier, Vt.

Western Society of Engineers, 1737 Monadnock Block, Chicago, Ill.

ACCESSIONS TO THE LIBRARY

(From November 2d to December 2d, 1916)

DONATIONS *

PASSENGER TERMINALS AND TRAINS.

By John A. Droege. Cloth, 9¼ x 6 in., illus., 7 + 410 pp. New York, McGraw-Hill Book Company, Inc.; London, Hill Publishing Co., Ltd., 1916. $5.00.

In 1912, the author published his "Freight Terminals and Trains", and it was then suggested that he cover the whole field of terminals and operation by issuing a companion work treating of the passenger service. This suggestion is carried out in the present volume, this book having been arranged with a view to producing two companion volumes covering the operation of freight and passenger train service, the design, construction, and maintenance of terminals and their accessories, as well as plans of organization and operating methods coincident thereto. As descriptions of all the existing passenger terminals was impossible, the author has included, it is stated, only such descriptions, views, and plans as embody typical or unique features possessing educational value. The Chapter headings are: General Principles; Construction and Maintenance Details; Interlocking and Approaches; Through or Side Stations; Head or Stub Stations; Water Front Terminals; The Passenger Terminals of New York City; Trackage or Terminal Agreements; Passenger Terminal Operation; The Station Master; The Ticket Office; Train Indicators; Baggage Handling and the Parcel Room; Car-cleaning Plants; Small Stations; Passenger Trains and Terminals of Foreign Countries; Electrification; Time-Tables and Train Schedules; Passenger Train Operation; Accidents and Their Prevention; The Commissary; Statistics of Passenger Service; Index.

CONTRACTS, SPECIFICATIONS AND ENGINEERING RELATIONS.

By Daniel W. Mead, M. Am. Soc. C. E. Cloth, 9¼ x 6 in., illus., 11 + 535 pp. New York, McGraw-Hill Book Co., 1916. $3.00.

In this book, which was first issued for use by the author's class at the University of Wisconsin and for private circulation, the author, it is said, has discussed some of the important relations of the engineer and architect in practical life, with which the technical man should familiarize himself before engaging in professional practice. The discussion of legal and contractual relations is brief, and although that on the principles of personal and ethical relations is also brief, it is stated in such a manner, it is said, as to make it plain to the young engineer that an appreciation of honesty, integrity, and fairness in his dealings with contractors and others, will lead to the highest type of work, the most economical construction, and the greatest professional satisfaction. The latter part of the book is devoted to a detailed discussion on the preparation of specifications, and the analytical system suggested by the author is believed, it is stated, to afford a safe and logical method for the student to follow in working out the elements and principles of specification writing. At the end of each chapter, the author has included a brief bibliography on the subject discussed in that chapter and, in Appendix D, he has given an extensive bibliography of specifications. The Contents are: The Engineer and His Education; Success in the Engineering Profession; The Engineer at Work; Personal and Ethical Relations; The Use of English; Letters and Reports; Origin, Nature and Development of Law; Some Legal Relations of Technical Men—Legal Rights and Responsibilities; Notes on Agreements and Contractual Relations; Day Labor and Contract Systems of Construction; Engineering and Architectural Works Constructed Under Contract; Advertising and Letting Contract; Contracts; General Conditions of the Contract; Preparation of Specifications; Technical Specifications; Specifications for Fundamental Materials and Supplies; Specifications for Fundamental Processes; Specifications for Machinery and Apparatus; Design and Specifications for Engineering and Architectural Work; Appendix A, Outline of Specifications for the Construction of a Building; Appendix B, Sample Contract and Specifications for a Complete Structure; Appendix C, Drawings as a Basis for Specification Writing; Appendix D, Bibliography of Specifications; Index.

Gifts have also been received from the following:

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Alabama-Geol. Survey. 1 pam.
Alvord, John W. 2 pam.
Am. Telephone & Telegraph Co. 1 vol., 2 pam.
Arnold, Bion J. 1 bound vol.
Assoc. Elettrotecnica Italiana. 1 pam.
British Fire Prevention Committee. 1 pam.
Brown, Rome G. 1 pam.

* Unless otherwise specified, books in this list have been donated by the publishers.

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Canada-Geol. Survey. 1 vol., 2 pam.
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North East Coast Inst. of Engrs. and Shipbuilders. 1 bound vol.
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U. S.-Engr. Office, Grand Rapids, Mich. 2 pam.
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U. S.-Engr. Office, New York City. 1 pam.
U. S.-Engr. Office, San Francisco, Cal. 2 pam.
U. S.-Engr. Office, Wheeling, W. Va. 4 pam.
U. S.-National Museum. 1 pam.
Universidad Nacional de la Plata. 1 pam.
Vermont Soc. of Engrs. 1 pam.
Virginian Ry. Co. 1 pam.

SUMMARY OF ACCESSIONS

(From November 2d to December 2d, 1916)

Donations 114

MEMBERSHIP

(From November 3d to December 7th, 1916)

ADDITIONS

MEMBERS

Members		Date of Membership.
ANDREWS, JAMES HENRY MILLAR. Engr. of Distrib., The Philadelphia Rap. Trans. System, 820 Dauphin St., Philadelphia, Pa.	Assoc. M. M.	April 2, 1912 Nov. 28, 1916
DAY, WILLIAM PEYTON. Archt. and Engr. (Weeks & Day), 933 Phelan Bldg., San Francisco, Cal.	Jun. Assoc. M. M.	Mar. 6, 1906 Mar. 1, 1910 Oct. 10, 1916
DUNN, GANO. Pres., The J. G. White Eng. Corporation, 117 West 58th St., New York City		Nov. 28, 1916
GAYLORD, LAURENCE TIMMERMAN. Vice-Pres., Atlantic, Gulf & Pacific Co., Park Row Bldg., New York City (Res., 182 Christopher St., Montclair, N. J.)	Assoc. M. M.	Nov. 4, 1908 Oct. 10, 1916
GIAVER, JOACHIM GOTSCHE. Cons. and Structural Engr., 751 Ry. Exchange Bldg., Chicago, Ill.		Sept. 12, 1916
HEALD, EUGENE HAMILTON. Asst. Div. Contr. Mgr., Am. Bridge Co., 208 South La Salle St., Chicago, Ill.		June 23, 1916
MACCREA, DON ALEXANDER. Cons. and Superv. Engr. (Ford & MacCrea), Room 338, Gazette Bldg., Little Rock, Ark.	Jun. Assoc. M. M.	May 2, 1899 Oct. 1, 1902 Nov. 28, 1916
MACINTYRE, ROBERT WENTWORTH. Asst. Engr., Dept. of Rys., Govt. of British Columbia, Box 1290, Victoria, B. C., Canada		Oct. 10, 1916
MONTZHEIMER, ARTHUR. Chf. Engr., Elgin, Joliet & Eastern Ry., Joliet National Bank Bldg., Joliet, Ill.		Nov. 28, 1916
POUCHER, GEORGE EDWARD. Engr., Drawing Room No. 1, Ambridge Plant, Am. Bridge Co., Ambridge, Pa.		Nov. 28, 1916
RIPLEY, HERBERT SPENCER. Res. Engr., Calumet-Sag Canal, Worth, Ill.		Nov. 28, 1916
ROBERTSON, AVALON GRAVES. Chf. Engr., Bocas Div., United Fruit Co., Bocas del Toro, Panama	Jun. Assoc. M. M.	Oct. 6, 1908 Jan. 3, 1911 Oct. 10, 1916
STAMM, NORMAN LESLIE. Harbor Engr., Dept. of Wharves, Docks and Ferries, City of Philadelphia, 3412 Race St., Philadelphia, Pa.		Nov. 28, 1916
STEVENS, HAROLD LYELL. Pres., H. L. Stevens & Co., 910 South Michigan Ave., Chicago, Ill.	Assoc. M. M.	April 6, 1909 Nov. 28, 1916
STRICKLER, THOMAS JOHNSON. Engr., Kansas Public Utilities Comm., Topeka, Kans.	Assoc. M. M.	May 3, 1910 Nov. 28, 1916
THOMPSON, MILTON THEODORE. 324 Westview Ave., Leonia, N. J.		Sept. 12, 1916

MEMBERS (*Continued*)

		Date of Membership.
TRIANA, MIGUEL. P. O. Box No. 5, Bogota, Colombia		Sept. 12, 1916
WHITE, ROBERT CULIN. Engr., M. of W., Southern Dist., Mo. Pac., Iron Mt. Ry., Room 20, Union Station, Little Rock, Ark.	Assoc. M. M.	June 4, 1913 Oct. 10, 1916
WHITNEY, ALFRED RUTGERS, JR. Pres. and Treas., The Whitney Co., 1 Liberty St., New York City		Sept. 12, 1916
ZAHNISER, GEORGE BROWN. Civ. and Min. Engr., Clendenin Blk., New Castle, Pa		Nov. 28, 1916

ASSOCIATE MEMBERS

ALLEE, ORSINO PAUL. Vice-Pres. and Mgr., Arkansas Bridge Co., 3414 Wyandotte St., Kansas City, Mo.		May 31, 1916
ALLEN, LUCIUS EPHRAIM. Cons. and Const. Engr., Bank of Commerce Bldg., Belleville, Ont., Canada		Nov. 28, 1916
BENJAMIN, WILLIAM PURDY. Supt. of Constr., The Babcock & Wilcox Co., Care, J. S. Sneddon, Barberton, Ohio		Mar. 14, 1916
BENNETT, HARRY. Engr. in Chg. of Constr. for Northwest Paper Co., Brainerd, Minn		Nov. 28, 1916
CHERRINGTON, FRANK WILLARD. Chf. Engr., The Jennison-Wright Co., 2463 Broadway, Toledo, Ohio		Nov. 28, 1916
CLARKSON, WILLIAM, JR. Asst. Mgr. and Chf. Engr., Oil City Iron Works, Corsicana, Tex		Nov. 28, 1916
CONARD, ROBERT ALLEN. Supt., Sewer Dept., Jacksonville, Fla.		May 31, 1916
DAVIS, FRANK HILL. U. S. Engr. Office, Tuscaloosa, Ala.		May 31, 1916
DERRICK, JOHN RUSSELL. Asst. Res. Engr., M. of W., N. & W. Ry., 723 Princeton Ave., Bluefield, W. Va	Jun. Assoc. M.	May 28, 1912 Sept. 12, 1916
FERGUSON, WILBUR EARLE. Estimating Engr., Robert A. Keasbey Co.; Instr., Civ. Eng., Cooper Union, Cooper Union, New York City		May 31, 1916
FINCH, FRANK HAMILTON. Asst. Engr., Designing and Estimating Eng. Dept., McClintic-Marshall Co., 1508 Hillsdale Ave., Dormont, Pa		Nov. 28, 1916
FOSTER, HERBERT BISMARCK. Engr. for Comptroller's Office, Univ. of California, Berkeley, Cal	Jun. Assoc. M.	Sept. 3, 1907 Oct. 10, 1916
FRANK, GEORGE STEDMAN. Asst. Constr. Supt., Commonwealth Acid-Phospate Co., Medford, Mass		Nov. 28, 1916
FRANKLAND, FREDERICK HERSTON. Bridge Engr., Highway Dept., Calcasieu Parish, P. O. Box 610, Lake Charles, La		May 31, 1916
GRIMM, CLAUDE IRVING. Junior Engr., U. S. Engr. Office, Box 716, Cincinnati, Ohio		Oct. 10, 1916

ASSOCIATE MEMBERS (*Continued*)

		Date of Membership.
GROSVENOR, ASA WATERS, Designing and Superv. Engr., 408 Bass Blk., Fort Wayne, Ind.		Nov. 28, 1916
HART, SAMUEL ALEXANDER. La Habra, Cal.		Oct. 10, 1916
HOHL, LEONARD LOUIS. Sausalito, Cal.	Jun. Assoc. M.	Sept. 4, 1905 Oct. 10, 1916
LEEDS, LIVINGSTON ALLAIRE. Asst. Engr., State Highway Dept., Poughkeepsie, N. Y.	Jun. Assoc. M.	May 6, 1914 Nov. 28, 1916
LEWIS, HAROLD MACLEAN. With Charles W. Leavitt, Loretto, Pa.	Jun. Assoc. M.	Feb. 4, 1913 Nov. 28, 1916
MCLAREN, ARTHUR ANTHONY. Supt. of Constr., Cedars Rapids Mfg. & Power Co., Cedars, Que., Canada	Jun. Assoc. M.	June 24, 1914 June 23, 1916
MCVEA, JOHN CRANE. Asst. City Engr., City Hall, Houston, Tex.		Nov. 28, 1916
MILLER, BENJAMIN FRANKLIN, JR. City Engr., 721 Alden St., Meadville, Pa.		June 23, 1916
NICHOLS, ALLEN EUGENE. Designing Engr., City of Chicago, 5331 Woodlawn Ave., Chicago, Ill.		Oct. 10, 1916
PATTERSON, LAURENCE. 435 Van Cortlandt Park Ave., Yonkers, N. Y.		May 31, 1916
PITNEY, JOHN JAMES GARFIELD. Engr. in Chg. of Squad, Am. Bridge Co., Box 13, Ambridge, Pa.		Oct. 10, 1916
PLUMP, ERICH MOORE. 401 Stuyvesant Ave., Brooklyn, N. Y.	Jun. Assoc. M.	April 30, 1912 Nov. 28, 1916
ROHDE, CHARLES FREEMAN. Asst. Engr., Public Service Comm., City of New York, 6830 Ridge Boulevard, Brooklyn, N. Y.		May 31, 1916
RUTHERFORD, EARL DOUGLAS. 709 Lyon and Healy Bldg., Chicago, Ill.		Nov. 28, 1916
SHAW, HOBART DOANE. City Engr., Gulfport, Miss.		Nov. 28, 1916
SORENSON, JULIUS JENNIS. Care, Valuation Dept., L. R. & N. Co., Shreveport, La.		June 23, 1916
STIMSON, BURT. 5265 Fifteenth Ave., N. E., Seattle, Wash.		Sept. 12, 1916
THOMAS, DAVID OGLE. Belleville, Ill.		Oct. 10, 1916
WICKER, WILLIAM SOMERS. Res. Engr., Chester & Fleming, 29 East Glenaven Ave., Youngstown, Ohio		Oct. 10, 1916
WINN, WALTER EDWARD. Chf. Engr., The Winn Eng. Co., 211 Solomon Bldg., Helena, Ark.		Nov. 28, 1916

ASSOCIATES

MOOTS, ELMER EARL. Care, Agricultural Products Co., Box 396, Tucson, Ariz.	May 31, 1916
WARREN, GEORGE COPP. Pres., Warren Bros. Co., 142 Berkeley St., Boston, Mass.	Nov. 28, 1916

JUNIORS

	Date of Membership.
Boland, Charles Joseph. Engr., C. P. Boland & Co., 228 Eighth St., Troy, N. Y.	Nov. 28, 1916
Camp, George Dashiell. 38 Westland Ave., Boston, Mass.	Sept. 12, 1916
Canney, Jay Cassius. Structural Draftsman, Bridge Dept., City of Seattle, 5054 Seventh Ave., N. E., Seattle, Wash.	May 31, 1916
Coombs, Donald Gladstone. Asst. to Supt. of Constr., U. S. Reclamation Service, Meadow Creek, Wash.	Sept. 12, 1916
Davies, Herbert Arthur. Care, Virginia Bridge & Iron Co., Roanoke, Va.	Mar. 14, 1916
Dupuy, Alberto. Apartado No. 893, Bogota, Colombia	Sept. 12, 1916
Libbey, Valentine Brousseau. 240 Benefit St., Providence, R. I.	Nov. 28, 1916
Neff, Henry Conrad. Civ. Engr., Town of Adams, First National Bank Bldg., Adams, Mass.	May 31, 1916
Stafford, Harlowe McVicker. Field Asst., Water Resources Branch, U. S. Geological Survey, Buck Meadows, P. O., Lake Eleanor (*via* Hetch Hetchy Valley), Cal.	Oct. 10, 1916

CHANGES OF ADDRESS

MEMBERS

Baker, Holland Williams. Cons. Engr., Cambridge Pl., Station A, Columbus, Ohio.

Barr, Joseph Carroll. Gen. Mgr., Pittsburgh Steel Ore Co., Riverton, Minn.

Brownell, Ernest Henry. Civ. Engr., U. S. N., Navy Yard, Portsmouth, N. H.

Burr, William Hubert. Cons. Engr., 120 Broadway, New York City.

Cameron, Harry Frank. Union, Me.

Conard, Clarence Knight. Chf. Engr., Davison Sulphur & Phospate Co., Hourruitiner 25, Cienfuegos, Cuba.

Crownover, Charles Elmer. Project Engr., U. S. Reclamation Service, North Yakima, Wash.

Edwards, James Harvey. Asst. Chf. Engr., Am. Bridge Co., 30 Church St., New York City.

Fitch, Charles Lincoln. Cons. Engr., 314 Hennen Bldg., New Orleans, La.

Gates, Horace Delphos. 6052 Ross St., Oakland, Cal.

Haines, Henry Stevens. 1154 Worthington St., Springfield, Mass.

Hall, Julius Reed. Mech. Engr., Snyder Elec. Furnace Co., 1405 Monadnock Blk., Chicago, Ill.

Hammond, Alonzo John. Prin. Asst. Engr., Chicago Union Station Co.; Res., 707 Michigan Ave., Evanston, Ill.

Harrison, Burr Powell. First Asst. Engr., Maryland State Road Comm., 218 East Biddle St., Baltimore, Md.

MEMBERS (*Continued*)

HAWLEY, WILLIAM CHAUNCEY. Chf. Engr. and Gen. Supt., Pennsylvania Water Co., 721 South Ave., Wilkinsburg, Pa.

HECK, KIRBY SCOTT. 1765 Atlantic Ave., Long Beach, Cal.

HOWARD, JOHN LEWIS. Asst. to Chf. Engr., Metropolitan Water-Works, 1 Ashburton Pl., Boston, Mass.

JACKSON, EDWARD SHERMAN. Supt. and Chf. Engr., Idaho South. R. R., 700 Kinnear Pl., Seattle, Wash.

JOHNSON, CHARLES. Asst. Engr., Coventry Land & Impvt. Co., 403 Ohio Boulevard (Res., 110 Russel Ave.), Akron, Ohio.

KHUEN, RICHARD, JR. (*Director.*) Gen. Mgr. of Erection, Am. Bridge Co., Frick Bldg., Pittsburgh, Pa.

McGREW, ANSON BURLINGAME. U. S. Asst. Engr., 211 Farmers Bank Bldg., Pittsburgh, Pa.

MATHEWSON, THOMAS KNIGHT. 1919 Mulberry Ave., Muscatine, Iowa.

MINNISS, GEORGE STEWART. Capt., 74th New York Infantry, Pharr, Tex.

NEWMAN, JEROME. Chf. Engr., Board of State Harbor Commrs., 1271 Twelfth Ave., San Francisco, Cal.

POLK, ARMOUR CANTRELL. Care, Sanderson & Porter, 52 William St., New York City.

ROWELL, GEORGE FREEMAN. Care, Day & Zimmermann, 611 Chestnut St., Philadelphia, Pa.

ROWLAND, WALTER. Asst. Engr., Chile Exploration Co., 120 Broadway, Room 3523, New York City.

SCHURIG, ERNEST GEORGE. Supt. of Constr., U. S. Treasury Dept., 34 Bishop St., New Haven, Conn.

SHEPLEY, CHARLES ROGERS. Contr. and Engr., 920 Germania Life Bldg., St. Paul, Minn.

STURTEVANT, CARLETON WILLIAM. Cons. Engr., 110 Cathedral Parkway, New York City.

THAYER, RUSSELL. Commercial Trust Bldg., Philadelphia, Pa.

TUTHILL, JOB. Michigan Central Terminal, Detroit, Mich.

WALSH, GEORGE SCHERZER. 2110 Garfield St., Lincoln, Nebr.

WOLFF, HANS HERMANN. Box 283, Berkeley Springs, W. Va.

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DEATHS

CUNTZ, WILLIAM COOPER. Elected Associate, September 6th, 1910; died November 2d, 1916.

ELLIS, JOHN WALDO. Elected Member, July 3d, 1895; died October 29th, 1916.

HOAG, SIDNEY WILLETT, JR. Elected Member, September 2d, 1885; died November 1st, 1916.

JAQUES, WILLIAM HENRY. Elected Member, July 2d, 1890; date of death unknown.

KATIGBAK, JOSÉ PETRONIO. Elected Associate Member, April 1st, 1914; died May 16th, 1916.

RATHMANN, LOUIS HENRY. Elected Member, May 2d, 1911; died November 17th, 1916.

ROSS, CHARLES WILSON. Elected Associate, February 28th, 1911; died April 11th, 1916.

ROY, ROBERT MAITLAND. Elected Associate Member, October 3d, 1900; Member, March 5th, 1907; died June 27th, 1916.

SINCLAIR, FRANK OSCAR. Elected Member, November 6th, 1901; died November 15th, 1916.

Total Membership of the Society, December 7th, 1916, 8 200.

MONTHLY LIST OF RECENT ENGINEERING ARTICLES OF INTEREST

(November 2d to December 2d, 1916)

NOTE.—*This list is published for the purpose of placing before the members of this Society, the titles of current engineering articles, which can be referred to in any available engineering library, or can be procured by addressing the publication directly, the address and price being given wherever possible.*

LIST OF PUBLICATIONS

In the subjoined list of articles, references are given by the number prefixed to each journal in this list:

(2) *Proceedings*, Engrs. Club of Phila., Philadelphia, Pa.
(3) *Journal*, Franklin Inst., Philadelphia, Pa., 50c.
(4) *Journal*, Western Soc. of Engrs., Chicago, Ill., 50c.
(5) *Transactions*, Can. Soc. C. E., Montreal, Que., Canada.
(6) *School of Mines Quarterly*, Columbia Univ., New York City, 50c.
(7) *Gesundheits Ingenieur*, München, Germany.
(8) *Stevens Institute Indicator*, Hoboken, N. J., 50c.
(9) *Engineering Magazine*, New York City, 25c.
(11) *Engineering* (London), W. H. Wiley, 432 Fourth Ave., New York City, 25c.
(12) *The Engineer* (London), International News Co., New York City, 35c.
(13) *Engineering News*, New York City, 15c.
(14) *Engineering Record*, New York City, 15c.
(15) *Railway Age Gazette*, New York City, 15c.
(16) *Engineering and Mining Journal*, New York City, 15c.
(17) *Electric Railway Journal*, New York City, 10c.
(18) *Railway Review*, Chicago, Ill., 15c.
(19) *Scientific American Supplement*, New York City, 10c.
(20) *Iron Age*, New York City, 20c.
(21) *Railway Engineer*, London, England, 1s. 2d.
(22) *Iron and Coal Trades Review*, London, England, 6d.
(23) *Railway Gazette*, London, England, 6d.
(24) *American Gas Light Journal*, New York City, 10c.
(25) *Railway Mechanical Engineer*, New York City, 20c.
(26) *Electrical Review*, London, England, 4d.
(27) *Electrical World*, New York City, 10c.
(28) *Journal*, New England Water-Works Assoc., Boston, Mass., $1.
(29) *Journal*, Royal Society of Arts, London, England, 6d.
(30) *Annales des Travaux Publics de Belgique*, Brussels, Belgium, 4 fr.
(31) *Annales* de l'Assoc. des Ing. Sortis des Ecoles Spéciales de Gand, Brussels, Belgium, 4 fr.
(32) *Mémoires et Compte Rendu des Travaux*, Soc. Ing. Civ. de France, Paris, France.
(33) *Le Génie Civil*, Paris, France, 1 fr.
(34) *Portefeuille Economiques des Machines*, Paris, France.
(35) *Nouvelles Annales de la Construction*, Paris, France.
(36) *Cornell Civil Engineer*, Ithaca, N. Y.
(37) *Revue de Mécanique*, Paris, France.
(38) *Revue Générale des Chemins de Fer et des Tramways*, Paris, France.
(39) *Technisches Gemeindeblatt*, Berlin, Germany, 0, 70m.
(40) *Zentralblatt der Bauverwaltung*, Berlin, Germany, 60 pfg.
(41) *Electrotechnische Zeitschrift*, Berlin, Germany.
(42) *Proceedings*, Am. Inst. Elec. Engrs., New York City, $1.
(43) *Annales des Ponts et Chaussées*, Paris, France.
(44) *Journal*, Military Service Institution, Governors Island, New York Harbor, 50c.
(45) *Coal Age*, New York City, 10c.
(46) *Scientific American*, New York City, 15c.
(47) *Mechanical Engineer*, Manchester, England, 3d.
(48) *Zeitschrift*, Verein Deutscher Ingenieure, Berlin, Germany, 1, 60m.
(49) *Zeitschrift für Bauwesen*, Berlin, Germany.
(50) *Stahl und Eisen*, Düsseldorf, Germany.
(51) *Deutsche Bauzeitung*, Berlin, Germany.
(52) *Rigasche Industrie-Zeitung*, Riga, Russia, 25 kop.
(53) *Zeitschrift*, Oesterreichischer Ingenieur und Architekten Verein, Vienna, Austria, 70h.
(54) *Transactions*, Am. Soc. C. E., New York City, $12.
(55) *Transactions*, Am. Soc. M. E., New York City, $10.

(56) *Transactions,* Am. Inst. Min. Engrs., New York City, $6.
(57) *Colliery Guardian,* London, England, 5d.
(58) *Proceedings,* Engrs.' Soc. W. Pa., 2511 Oliver Bldg., Pittsburgh, Pa., 50c.
(59) *Proceedings,* American Water-Works Assoc., Troy, N. Y.
(60) *Municipal Engineering,* Indianapolis, Ind., 25c.
(61) *Proceedings,* Western Railway Club, 225 Dearborn St., Chicago, Ill., 25c.
(62) *Steel and Iron,* Thaw Bldg., Pittsburgh, Pa., 10c.
(63) *Minutes of Proceedings,* Inst. C. E., London, England.
(64) *Power,* New York City, 5c.
(65) *Official Proceedings,* New York Railroad Club, Brooklyn, N. Y., 15c.
(66) *Journal of Gas Lighting,* London, England, 6d.
(67) *Cement and Engineering News,* Chicago, Ill., 25c.
(68) *Mining Journal,* London, England, 6d.
(69) *Der Eisenbau,* Leipzig, Germany.
(71) *Journal,* Iron and Steel Inst., London, England.
(71*a*) *Carnegie Scholarship Memoirs,* Iron and Steel Inst., London, England.
(72) *American Machinist,* New York City, 15c.
(73) *Electrician,* London, England, 18c.
(74) *Transactions,* Inst. of Min. and Metal., London, England.
(75) *Proceedings,* Inst. of Mech. Engrs., London, England.
(76) *Brick,* Chicago, Ill., 20c.
(77) *Journal,* Inst. Elec. Engrs., London, England, 5s.
(78) *Beton und Eisen,* Vienna, Austria, 1, 50m.
(79) *Forscherarbeiten,* Vienna, Austria.
(80) *Tonindustrie Zeitung,* Berlin, Germany.
(81) *Zeitschrift für Architektur und Ingenieurwesen,* Wiesbaden, Germany.
(82) *Mining and Engineering World,* Chicago, Ill., 10c.
(83) *Gas Age,* New York City, 15c.
(84) *Le Ciment,* Paris, France.
(85) *Proceedings,* Am. Ry. Eng. Assoc., Chicago, Ill.
(86) *Engineering-Contracting,* Chicago, Ill., 10c.
(87) *Railway Maintenance Engineer,* Chicago, Ill., 10c.
(88) *Bulletin* of the International Ry. Congress Assoc., Brussels, Belgium.
(89) *Proceedings,* Am. Soc. for Testing Materials, Philadelphia, Pa., $5.
(90) *Transactions,* Inst. of Naval Archts., London, England.
(91) *Transactions,* Soc. Naval Archts. and Marine Engrs., New York City.
(92) *Bulletin,* Soc. d'Encouragement pour l'Industrie Nationale, Paris, France.
(93) *Revue de Métallurgie,* Paris, France, 4 fr. 50.
(95) *International Marine Engineering,* New York City, 20c.
(96) *Canadian Engineer,* Toronto, Ont., Canada, 10c.
(98) *Journal,* Engrs. Soc. Pa., Harrisburg, Pa., 30c.
(99) *Proceedings,* Am. Soc. of Municipal Improvements, New York City, $2.
(100) *Professional Memoirs,* Corps of Engrs., U. S. A., Washington, D. C., 50c.
(101) *Metal Worker,* New York City, 10c.
(102) *Organ für die Fortschritte des Eisenbahnwesens,* Wiesbaden, Germany.
(103) *Mining and Scientific Press,* San Francisco, Cal., 10c.
(104) *The Surveyor and Municipal and County Engineer,* London, England, 6d.
(105) *Metallurgical and Chemical Engineering,* New York City, 25c.
(106) *Transactions,* Inst. of Min. Engrs., London, England, 6s.
(107) *Schweizerische Bauzeitung,* Zürich, Switzerland.
(108) *Iron Tradesman,* Atlanta, Ga., 10c.
(109) *Journal,* Boston Soc. C. E., Boston, Mass., 50c.
(110) *Journal,* Am. Concrete Inst., Philadelphia, Pa., 50c.
(111) *Journal of Electricity, Power and Gas,* San Francisco, Cal., 25c.
(112) *Internationale Zeitschrift für Wasser-Versorgung,* Leipzig, Germany.
(113) *Proceedings,* Am. Wood Preservers' Assoc., Baltimore, Md.
(114) *Journal,* Institution of Municipal and County Engineers, London, England, 1s. 6d.
(115) *Journal,* Engrs.' Club of St. Louis, St. Louis, Mo., 35c.
(116) *Blast Furnace and Steel Plant,* Pittsburgh, Pa., 15c.

LIST OF ARTICLES

Bridges.

Erection of an Arched Bridge.* Walter Smith. (Extract from paper read before the Inter. Ry. Foremans' Assoc.) (21) Sept.
Concrete Viaducts on the Chicago, Milwaukee and St. Paul.* (23) Sept. 29.
Ferro-Concrete Bridges in the Turch Valley, Glamorganshire.* (104) Oct. 27.
Erection of the South Cantilever Arm of the New Quebec Bridge.* (12) Oct. 27.
Design of Symmetrical Hingeless Concrete Arches.* Victor H. Cochrane. (58) Nov.
The Quebec Bridge.* (21) Nov.
Arch Centers Suspended from Old Plate Girders.* (13) Nov. 2; (87) Dec.
The Bloor-Street Viaduct, Toronto.* (12) Nov. 3.

* Illustrated.

Bridges—(Continued).

Special Protection for a Drawbridge.* (15) Nov. 3.
Jacking Up a Viaduct; Buckling Columns Give Trouble.* (13) Nov. 9; (14) Nov. 4.
Proposed Motor-Truck Loads for Highway Bridges.* O. W. Childs. (13) Nov. 9.
Construction of Two Concrete Arch Bridges at Rosalia, Wash.* J. F. Pinson. (Abstract from paper read before the Am. Ry. Bridge and Building Assoc.) (18) Nov. 11.
Novel Method of Erection Adopted in Raising Longest Highway Arch Span.* (14) Nov. 11.
Erection Methods, Bloor-Street Viaduct, Toronto.* J. Gordon Jack. (96) Nov. 16.
Quebec Bridge Disaster.* (96) Nov. 16.
Viaduct 170 Ft. High Erected Without Falsework by Special Steel Struts.* (14) Nov. 18.
I-Beam and Concrete Highway Bridges in Adams County, Indiana.* (86) Nov. 22.
A 4 700-Ft. Concrete Bridge.* (86) Nov. 22.
Concreting Plant for Construction of Rosalia, Wash., Bridges of C., M. & St. P. Ry.* (86) Nov. 22.
A 160-Ft. Wide Bridge and Some Notes on the Construction Plant.* (86) Nov. 22.
Slab-Deck Concrete Railway Bridge Over Highway (13) Nov. 23.
New Bridge at Kiskiminetas Junction, Pa. (15) Nov. 24.
Bascule Bridge for Highway Service in California.* (14) Nov. 25.
Asbestos Sheathing Protects Steel Overhead Bridge.* (14) Nov. 25.
Maintenance Painting of Bridges.* W. S. Lacher. (Paper read before Maintenance of Way Master Painters' Assoc.) (87) Dec.
Discuss Illinois Bridge Specifications. (From Report to Chicago Assoc. of Commerce.) (14) Dec. 2.
Grade Crossing Is Eliminated by Special Construction Methods to Maintain Traffic.* (14) Dec. 2.
Difficult Problems Solved in Placing New Members and Larger Pins in Drawspan.* (14) Dec. 2.
Note sur la Resturation du Pont de Trilport.* Wender. (43) Mar.–Apr.
Ponts a Arcades, Système Vierendeel: Nouvelle Méthode de Calcul Approché.* (33) Oct. 21.
Angenäherte Berechnung einer Eingespannten Eisenbetonbrücke.* H. Pilgrim. (78) Oct. 3.
Der Montagenfall beim Bau der St. Lawrence-Brücke bei Quebec, am 11 September 1916.* (107) Nov. 4.

Electrical.

Balancers on Three-Wire System.* H. M. Phillips. (64) Oct. 3.
Central Station for Power in Steel Mills. (Abstract of paper read before Assoc. of Iron and Steel Electrical Engrs.) (64) Oct. 3.
Two-Speed Alternating-Current Elevator Motors.* (64) Oct. 10.
Expansion Joints in Electric Cables.* (23) Oct. 13.
Synchronous Converters.* F. A. Annett and Gordon Fox. (64) Serial beginning Oct. 17.
New Type of Choke Coil.* (64) Oct. 17.
On an Unbroken Alternating Current for Cable Telegraphy. G. O. Squier. (Abstract from paper read before the Physical Soc. of London.) (73) Oct. 20.
Economy of Electricity in Small Households. W. B. Smith. (Abstract of paper read before Greenock Electrical Soc.) (73) Oct. 20.
A New Marconi 0.25 K. W. Installation.* (73) Oct. 20.
New Fremont, Ohio, Power Plant.* Warren O. Rogers. (64) Oct. 24.
Possibilities of Stage Lighting.* Bassett Jones. (Abstract of paper read before Illuminating Eng. Soc.) (73) Oct. 27.
Industrial Lighting by Electricity. Frederick H. Taylor. (Paper read before the Junior Inst. of Engrs.) (47) Oct. 27; (26) Oct. 27.
Protection of Electrical Installations Against Surges.* (Abstract of Report from *Bulletin No. 6* of the Schweizer. Elektrotechn. Verein.) (73) Oct. 27.
Use of Ionised Air in Agriculture.* Ingvar Jorgensen. (26) Serial beginning Oct. 27.
Rational Temperature Guarantees for Large A.-C. Generators.* F. D. Newbury. (42) Nov.
Cost *vs.* Upkeep of Direct-Current Motors. A. M. MacCutcheon. (116) Nov.
Temperature Distributions in Electrical Machinery.* B. G. Lamme. (42) Nov.
Progress of Economic Power Generation and Distribution.* Samuel Insull. (55) Nov.
Quantitative Measurements at Washington on the Signals from the German Radio Stations at Nauen and Eilvese.* L. W. Austin. (3) Nov.
British Westinghouse Rotary Converters.* (73) Nov. 3.
End-Rings.* R. Roberts. (73) Nov. 3.
Electricity Supersedes Steam for Heating Shoe Machinery in Brockton (Mass.) Factory.* (27) Nov. 4.
Heat Energy and Electricity. E. A. Wilcox. (111) Nov. 4.

* Illustrated.

Electrical—(Continued).

New Invention for Measuring Currents in Cables.* C. B. Merrick. (111) Nov. 4.
Duplexing in the Squier System of Telegraphy.* Louis Cohen. (73) Nov. 10.
Tests to Determine Heating of Underground Cables.* Henry A. Cozzens, Jr. (27) Nov. 11.
Standard Electrical Specifications. H. Conger Bowers. (111) Nov. 11.
New Steam Generating Station for Cincinnati. (27) Nov. 11.
Electric Power Transmission in Logging. Allen E. Ransom. (111) Nov. 11.
Developments in Meter Testing Methods and Apparatus.* Otto A. Knopp. (27) Nov. 11.
Characteristics of Electric Reversing Mill.* J. E. Jefferies. (Abstract of paper read before Assoc. of Iron and Steel Elec. Engrs.) (27) Nov. 11.
Proper Current Densities.* B. B. Hood. (105) Nov. 15.
An Analysis of Tank Resistance in Electrolytic Refining.* Lawrence Addicks. (105) Nov. 15.
Liquid Rheostatic Control for Large Alternating Current Wound-Rotor Motors.* (86) Nov. 15.
Direct and Indirect Methods of Making Nitric Acid. E. Kilburn Scott. (Abstract of lecture delivered at University College, London.) (73) Nov. 17.
An Apparatus for the Commercial Testing of Permanent Magnets.* G. B. Betteridge. (73) Nov. 17.
Protecting Manhole Cables Against Explosions of Those Adjacent. Albert F. Honey. (27) Nov. 18.
Losses in Cables Armored with Steel Tape.* W. I. Middleton and E. W. Davis. (27) Nov. 18.
Construction and Layout of High-Tension Equipment.* M. M. Samuels. (27) Nov. 18.
Theory and Operation of Split-Phase Magnet.* F. Hymans. (27) Serial beginning Nov. 18.
Ventilation of Battery Rooms. M. A. Walker. (64) Nov. 21.
Electric Lighting of a "Movie" Studio. W. E. Brewster. (27) Nov. 25.
Installation of Electric Heating Apparatus. E. A. Wilcox. (111) Nov. 25.
Lighting a Small Town.* (Titusville, Pa.) (27) Nov. 25.
Shunt Phase Converter.* W. J. Foster. (64) Nov. 28.
Essex Power Station.* (New Jersey.) (64) Nov. 28.
Motor-Operated End-Cell Switch.* D. P. Orcutt. (64) Nov. 28.
Induction Voltage Regulators.* (64) Nov. 28.
Electrolytic Hydrogen: A Modern Method for the Technical Production of an Important Gas.* Harry L. Barnitz. (19) Dec. 2.
Renseignements Recueillis au Cours d'un Récent Voyage aux Etats-Unis sur Quelques Applicatións et Tendancies Nouvelles dans le Domaine de la Mécanique et de l'Electricité. M. K. Sosnowski. (32) Apr.-June.

Marine.

Twin-Screw Motor-Ship *Ahelia.** (11) Serial beginning Oct. 20.
Voltaic Corrosion and Its Prevention* (Ship metal). Thomas J. Rogers. (From *International Marine Engineering.*) (47) Oct. 20.
Longitudinal Stresses of Ships.* Arthur Liddell. (12) Oct. 20.
Motor Tank Ship *Hamlet.** (12) Oct. 20.
Large Steel-Frame Ship Shed Contains Special Trusses Designed for Vertical and Horizontal Crane Loading.* (14) Nov. 4.
Future of the Marine Oil Engine.* John F. Wentworth. (From *International Marine Engineering.*) (47) Nov. 10.
Our Latest Dreadnought, the *Arizona.** (46) Nov. 25.
Supplying Water to River and Lake Ships.* (101) Dec. 1.

Mechanical.

Mechanical Coal Stage, Dairycoates, Hull.* (23) Sept. 1.
Commercial Motor Vehicles for Railway and Industrial Purposes; Tilling-Stevens Petrol-Electric Vehicles.* (23) Sept. 8.
Use of Motor Vehicles in Municipal Works; Mechanical *v.* Horse Traction. H. Shaw. (104) Serial beginning Sept. 15.
Electric *v.* Horse Haulage: South Shields Statistics. Leslie Roseveare. (104) Sept. 22.
Boiler Corrosion by Magnesium Chloride.* James Scott. (21) Oct.
Belt-Conveyor Operating Data.* John D. Morgan. (64) Oct. 3.
Largest Boilers for Ford Co.* J. P. Badenhausen. (64) Oct. 3.
Effect of Water Upon Carbon. Glenn Warren. (64) Oct. 3.
Handling Coal and Ashes at Grundy Plant.* Henry J. Edsall. (64) Oct. 3.
Vibration in Steam Turbines. H. A. Fisher. (64) Oct. 3.
Motor-Driven Compressor at Britannia Colliery.* (22) Oct. 6.
Testing Absorption Plants.* Julian C. Smallwood. (64) Oct. 10.
Clinkering of Bituminous Coal.* F. C. Hurley. (64) Serial beginning Oct. 10.

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Stoking Small Anthracite Coal.* Warren O. Rogers. (64) Oct. 17.
Mechanical Design of Turbo-Generators. William Knight. (64) Oct. 17.
Carburetion with Different Grades of Fuel.* E. N. Percy. (64) Oct. 17.
Twenty Years' Progress in Die Making and Using.* Edward Dean. (72) Serial beginning Oct. 19.
High Pressure Air-Compressors.* Joseph M. Ford. (Paper read before Greenock Assoc. of Shipbuilders and Engrs.) (11) Serial beginning Oct. 20.
Coke Handling Plant. A. B. Walker. (Abstract of paper read before the North of England Gas Managers' Assoc.) (57) Oct. 20.
Reducing Foundry Costs by Analysis.* R. E. Kennedy. (Paper read before the Am. Foundrymen's Assoc.) (47) Oct. 20.
Gas Burners for Industrial Work.* (12) Oct. 20.
Electricity and the Economical Use of Coal. R. A. Chattock. (Abstract of paper read before Birmingham Assoc. of Mech. Engrs.) (12) Oct. 20.
Modern Steam Laundry Machinery.* (12) Serial beginning Oct. 20.
Pressure Oil Film Lubricating. H. T. Newbigin. (Abstract of paper read before the British Assoc., Section G.) (26) Oct. 20.
Tests of Lubricating Oils. J. L. Kauffman. (Abstract from *Journal*, Am. Soc. Naval Engrs.) (47) Oct. 20.
Diversified Service for Diesel Engines.* (64) Oct. 24.
Gas Fire Construction. Harold Hartley. (From paper read before the Scottish Junior Gas Assoc., Eastern Dist.) (66) Oct. 24.
Heavy Work in an Hawaiian Shop.* (72) Oct. 26.
Manufacturing a Top Plate for a Typewriter.* Frank A. Stanley. (72) Serial beginning Oct. 26.
A Petrol Scraper Shovel.* (12) Oct. 27.
Use of Titanium in Steel Castings. W. A. Janssen. (Paper read before the Am. Foundrymen's Assoc.) (47) Oct. 27.
Use of Borings in Cupola Operations. James A. Murphy. (Paper read before the Am. Foundrymen's Assoc.) (47) Oct. 27; (22) Oct. 6.
Centrifugal Boiler Feed Pumps.* Otto Haentjens and Edward F. Barrett. (64) Oct. 31.
Selection of Electrical Apparatus for Cranes.* R. H. McLain and J. A. Jackson. (Abstract from *General Electric Review*.) (73) Oct. 27.
Notes on Purification.* W. C. Jones. (Paper read before the Midland Assoc. of Gas Engrs. and Mgrs.) (66) Oct. 31.
Review of Some Ammonia Explosions.* Charles H. Bromley. (64) Oct. 31.
Some Notes on Benzol Recovery and Rectification.* P. D. Walmsley and H. A. Morfey. (Paper read before the Inst. of Gas Engrs., Manchester Dist.) (66) Oct. 31; (22) Nov. 10.
Proposed Code of Safety Standards for Operation of Cranes. (Abstract.) (55) Nov.
Liquid Measuring Pumps. F. J. Schlink. (Abstract from U. S. Bureau of Standards *Technologic Paper No. 81*.) (3) Nov.
Use of Grinding Wheels in the Saw Mill.* C. E. Gillett. (108) Nov.
Internal-Combustion Motor for Traction Engines.* A. A. Potter and W. A. Buck. (Abstract.) (55) Nov.
Water for Steam Boilers—Its Significance and Treatment. Arthur C. Scott and J. R. Bailey. (Abstract.) (55) Nov.
The Proportioning of Surface Condensers. George A. Orrok. (Abstract.) (55) Nov.
Utilization of Waste Heat for Steam-Generating Purposes.* Arthur D. Pratt. (Abstract.) (55) Nov.
More Data on Test of Montreal Centrifugal Pump. A. Peterson. (13) Nov. 2.
Machining a Gas-Motor Crank Case.* Fred F. Bowen. (72) Nov. 2.
Inverted Drilling of Shell Blanks.* A. F. Menzies. (72) Nov. 2.
American Tests on Fish Bolts. (22) Nov. 3.
Tests of Williams & Robinson Condensers.* (73) Nov. 3; (26) Nov. 3; (12) Nov. 3.
Friction Clutches. William G. Gass. (Paper read before Manchester Assoc. of Engrs.) (47) Nov. 3.
Jigging Conveyor Underground and Methods of Working.* W. A. Machin. (Paper read before the National Assoc. of Colliery Mgrs.) (22) Nov. 3.
How to Gate and Head Steel Castings Properly.* Ralph D. West. (Abstract of paper read before Am. Foundrymen's Assoc.) (47) Nov. 3.
Coal-Face Conveyors Employed in the United Kingdom.* Sydney F. Walker. (45) Serial beginning Nov. 4.
Equipping Motor Trucks for Central Station Service.* (27) Nov. 4.
Oxy-Acetylene Welding Rapidly Taking Its Place in Distribution Work as a Means by Which Many Things Hitherto Considered Impossible can be Accomplished. Charles Wilde. (Abstract from paper read before the Am. Gas Institute.) (24) Nov. 6.
Industry Needs a Flexible Tubing in Which it Will be Safe to Allow the Gas Pressure to Remain at All Times.* (Abstract of paper read before the Am. Gas Institute.) (24) Nov. 6.

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Kiln Arches.* Earl E. Libmau. (76) Nov. 7.
Windsor Street Installation of Woodall-Duckham Vertical Retorts.* G. C. Pearson. (Paper read before the Midland Junior Gas Assoc.) (66) Nov. 7.
Gas Analysis Applied to Brick Kilns. F. D. Harger. (76) Nov. 7.
Continuous Drilling.* W. G. Groocock. (72) Nov. 9.
Construction of Machinery for Laundries.* Frank A. Stanley. (72) Serial beginning Nov. 9.
Measuring the Flow of Compressed Air.* Thomas G. Estep. (20) Nov. 9.
Determination of Foundry Costs. Clinton H. Scovell. (Abstract of paper read before Am. Foundrymen's Assoc.) (47) Nov. 10.
Electrically-Driven Floating Cranes.* (73) Nov. 10.
Uniflow Engines.* W. Trinks. (Abstract of paper read before the Am. Assoc. of Iron and Steel Electrical Engrs.) (47) Nov. 10.
Twin Engineering Works of the Fiat San Giorgio Company.* (11) Nov. 10.
Electric Vans for Laundry Work. (26) Nov. 10.
Aerial Tramway at Niagara Falls.* (17) Nov. 11.
Machinery for Mitchell Type of Rectangular Coke Oven.* H. V. Schiefer. (45) Nov. 11.
Motor-Truck Legislation Advocated in Michigan. (Extract from Report to Board of County Road Commrs.) (14) Nov. 11.
Centrifugal *versus* Reciprocating Boiler Feed Pumps.* M. William Ehrlich. (27) Nov. 11.
Overhauling Turbine Unit and Its Auxiliaries. (27) Nov. 11.
Ability of Artificial Fibre Mantle to Withstand Shocks After Long Period in Service Little Less Than it was Originally.* E. L. Knoedler. (Abstract of paper read before Joint Meeting of Illuminating Eng. Soc. and Am. Electro-chemical Soc.) (24) Nov. 13; (105) Dec. 1.
Considerable Reliance may be Placed on Cracking Data as Furnishing a Correct Means Valuating Gas Oils.* R. C. Downing and E. F. Pohlman. (Abstract from paper read before Am. Gas Institute.) (24) Nov. 13.
Briquetting Plant at the Smethwick Gas-Works.* (66) Nov. 14.
Refractory Materials. (Discussion at Meeting of the Faraday Soc.) (66) Nov. 14; (47) Serial beginning Nov. 16; (22) Nov. 10; (57) Nov. 10; (11) Nov. 10.
Excess Air in Fuel Combustion.* Morgan B. Smith. (64) Nov. 14.
Town Gas as a Fuel for Furnaces. E. P. Tandevin. (Abstract of paper read before Midland Junior Gas Assoc.) (66) Nov. 14.
Compression from a Mechanical Point of View.* F. R. Law. (64) Nov. 14.
The Brass Foundry. E. A. Barnes. (Paper read before the Am. Inst. of Metals.) (105) Nov. 15.
Apparatus and Operations in By-Product Recovery.* (83) Nov. 15.
Lubrication of Bearings. William Knight. (72) Nov. 16.
Safety Around Coke Ovens. Kenneth M. Burr. (Paper read before the National Safety Council.) (20) Nov. 16.
System of Special Holders with Inserted Cutters.* Earl L. Liddell. (72) Nov. 16.
Thermal Reactions of Cast Iron.* Thomas Turner. (Paper read before Am. Foundrymen's Assoc.) (47) Nov. 17.
Overhead Expense Items for Steam Fitters. (101) Nov. 17.
The Flying Service, from a Medical Point of View. Hardy U. Wells. (Abstract of paper from *Journal of Royal Naval Medical Service.*) (19) Nov. 18.
Testing of Automobile Motors.* Ferdinand Jehle. (From *Sibley Journal of Engineering.*) (19) Nov. 18.
Truck with Steel Tires Solves Difficult Haulage Problem.* (14) Nov. 18.
Draft and Its Application to the Steam Boiler. E. A. Uehling. (64) Nov. 21.
Ford Gas-Steam Plant.* Thomas Wilson. (64) Nov. 21.
Cast-Iron Pipe Manufacture in the South.* Y. A. Dyer. (20) Nov. 23.
Electric Motor in the Steel Mill.* H. F. Stratton. (20) Nov. 23.
Manufacture of Punchings.* C. W. Starker. (72) Nov. 23.
Operations on Sugar Machines in Honolulu.* Frank A. Stanley. (72) Nov. 23.
Analysis of Various Types of Irrigation Pumps.* R. H. Cates. (111) Nov. 25.
Concrete Tipple in Ohio.* William G. Burroughs. (45) Nov. 25.
Surface Combustion Affords Efficient Means of Converting Coal-Fired Brick Bake Ovens to Gas.* Henry L. Read. (24) Nov. 27.
Electric-Arc Welding.* (From Report to Assoc. of Ry. Electrical Engrs.) (64) Nov. 28.
Electric Ovens in an Automobile Plant.* (20) Nov. 30.
An Automatic Notching Die.* Frank A. Stanley. (72) Nov. 30.
Double-Helical Gear Cutter.* (72) Nov. 30.
Screw Machine Equipment.* Oskar Kylin. (20) Nov. 30.
Clinching 8-In. Shells.* H. V. Haight. (72) Nov. 30
Commercial Sampling and Analysis of Producer Gas.* Philip W. Swain. (Abstract.) (55) Dec.
Analysis of Marine Safety Valves.* E. F. Maas. (Abstract.) (55) Dec.
The Talbot Boiler.* Paul A. Talbot. (Abstract.) (55) Dec.
Standardization of Machine Tools.* Carl G. Barth. (Abstract.) (55) Dec.

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Mechanical—(Continued).

Graphic Methods of Analysis in the Design and Operation of Steam Power Plants.* R. J. S. Pigott. (Abstract.) (55) Dec.
Power Plant Efficiency.* Victor J. Azhe. (Abstract.) (55) Dec.
A Gas Producer for Bituminous Fuel.* O. C. Berry. (Abstract.) (55) Dec.
Determination of Light Oils in Coal Gas and Description of Still for Separating the Light Oils from the Absorbing Oil.* D. H. Duvall. (105) Dec. 1.
Note à Propos de la Communication de M. S. Périsse: Experiences et Etudes de Charles Weyher les Tourbillon Aériens et sur l'Ether. P. Juppont. (32) Apr.–June.
Feuerungsanlagen mit künstlichem Zug.* (107) Oct. 7.

Metallurgical.

Ideal Electrical Furnace for the Steel Foundry.* F. J. Ryan, E. E. McKee, and W. D. Walker. (Abstract of paper read before the Am. Foundrymen's Assoc.) (22) Oct. 6.
Electric Furnace Practice in the Manufacture of Steel Castings.* T. S. Quinn. (Abstract of paper read before the Am. Foundrymen's Assoc.) (22) Oct. 13.
Late Progress in Hot Blast Stove Design. Arthur J. Boynton. (116) Serial beginning Nov.
Pulverized Coal as a Metallurgical Fuel. James Wheeler Fuller. (Paper read before the Am. Iron and Steel Institute.) (116) Nov.; (20) Nov. 2.
Duplexing as Practised at Lackawanna.* George B. Waterhouse. (Paper read before the Am. Iron and Steel Institute.) (116) Nov.
Design of Mills for Flat Flanged Beams.* Fr. Denk. (116) Serial beginning Nov.
Saving on Slag through Efficient Crushing.* H. V. Schiefer. (116) Nov.
Heat Treatment for Special Alloy Steels.* Robert R. Abbott. (Paper read before the Penn. Section, Soc. of Automobile Engrs.) (62) Nov.
Thermoelectric Measurement of the Critical Ranges of Pure Iron. George K. Burgess and H. Scott. (Abstract from U. S. Bureau of Standards *Scientific Paper No. 296.*) (3) Nov.; (11) Oct. 20.
Chemical and Physical Properties of Foundry Irons.* J. A. Johnson, Jr. (105) Serial beginning Nov. 1.
Gronwall-Dixon Electric Melting and Refining Furnace.* John A. Cowley. (Paper read before Am. Foundrymen's Assoc.) (22) Nov. 3; (22) Nov. 3.
Electric *vs.* Converter Steel. Peter Blackwood. (Abstract of paper read before Am. Foundrymen's Assoc.) (22) Nov. 3.
Flotation Tests on an Antimony Gold Ore. Earl R. Pilgrim. (16) Nov. 4.
Determining Carbon in Steel by Combustion.* Jacob W. Barbey. (20) Nov. 9.
Influence of Copper in Corrosion of Steel Sheets. E. A. Richardson and L. T. Richardson. (Abstract of paper read before the Am. Electrochemical Soc.) (101) Nov. 10.
Alaska Has One Up-to-Date Flotation Plant—the Kennecott. Henricus J. Stander. (82) Nov. 11.
Milling and Cyaniding Costs at Grass Valley and Nevada City, California, in 1915. R. E. Tremoureux and F. A. Vestal. (103) Nov. 11.
Importance of Efficient Settling of Slime.* Paul W. Avery. (103) Nov. 18.
Advancements and Present Status of Preferential Flotation. Henricus J. Stander. (82) Nov. 18.
Bisulphite Process.* (16) Nov. 18.
Nevada Wonder Mill.* Arthur C. Daman. (16) Nov. 25.
Flotation. Henricus J. Stander. (Paper read before Am. Mining Congress.) (82) Nov. 25.
Strontium Nitrate—A New Industry.* Donal F. Irwin. (103) Nov. 25.
Present Status of the Ore Flotation Process. D. A. Lyon and O. C. Ralston. (Paper read before Am. Mining Congress.) (82) Nov. 25.
Winona Copper-Leaching Test Plant. (16) Nov. 25.
Electrolytic Zinc Dust. Harry J. Morgan and Oliver C. Ralston. (Paper read before Am. Electrochemical Soc.) (103) Nov. 25.
Flotation at the Calaveras Copper—A Simple Flow-Sheet.* Hallet R. Robbins. (103) Nov. 25.
Design of Acid-Resisting Iron Apparatus.* Norman Swindin. (From *Chemical Trade Journal and Chemical Engineer.*) (105) Dec. 1.
Mechanical Property of Certain Magnetized Bodies.* E. F. Northrup. (105) Dec. 1.
On the Formation of Columnar and of Free Crystals During Solidification.* Henry M. Howe. (405) Dec. 1.
Aarganische und schweizerische Eisenproduktion in Vergangenheit und Zukunft.* A. Trautweiler. (Paper presented at the 34th meeting of the G. E. P. in Baden.) (107) Serial beginning Oct. 28.

Military.

Railway Supply-Cities for Feeding the Firing Line in France.* (23) Sept. 15.
Two Years of Submarine Warfare. (12) Serial beginning Oct. 20.
Submarine Mine Wharf at Fort Armstrong, T. H.* Charles J. Taylor. (100) Nov.

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Torpedo Screen for Ships Under Way.* John B. Flowers. (46) Nov. 4.
Engineers for the Officers' Reserve Corps. A. H. Babcock. (103) Nov. 18.
When Fulton Suggested Submarine Warfare.* (46) Nov. 18.
Plants of Remington Arms Co.* Hugh M. Wharton. (72) Serial beginning Nov. 23.
Inspection and Tests of Lewis Machine Guns.* (46) Nov. 25.

Mining.

Some Properties of Water in Coal.* H. C. Porter and O. C. Ralston. (Abstract from *Technical Paper*, U. S. Bureau of Mines.) (22) Oct. 6; (57) Nov. 10.
Electric Signalling in Collieries.* (22) Oct. 13.
Iron Pyrites and the Oxidation of Coal. T. J. Drakeley. (From *Journal* of the Chemical Soc.) (57) Oct. 20.
Grinding Stone Dust at Caeran Colliery.* (22) Oct. 20.
Mine Car Design.* Marcus L. Hyde. (From Canadian Mining Institute *Bulletin*.) (57) Oct. 27.
Extraction of Coal by Solvents. F. Fischer and W. Glund. (57) Oct. 27.
Triplicate Sampling of Coal.* W. D. Stuckenberg. (64) Oct. 31.
New Methods for Mining Bituminous Coal as Practiced by the H. C. Frick Coke Company.* Patrick Mullen. (58) Nov.
Model of a Remarkable Gold Dredge.* (72) Nov. 2.
Effects of Oxygen Deficiency on Small Animals and on Men. George A. Burrell and G. G. Oberfell. (From *Technical Paper No. 122*, U. S. Bureau of Mines.) (22) Nov. 3.
Hydraulic Packing at Ballarpur Colliery, Central Provinces.* R. S. Davies. (From *Transactions*, Mining and Geological Inst. of India.) (57) Nov. 3.
New Belgian Coal Washer.* (57) Nov. 3.
Coal Mine Dynamometer Car.* (45) Nov. 4.
Measuring with the Steel Tape in Mine Surveying.* Walter Scott Weeks. (103) Nov. 4.
Improved Magnetic Separator.* August F. Jobke. (16) Nov. 4.
Sinking the Wallenberg Shaft.* Lloyd D. Cooper. (16) Nov. 4.
Coal Dust Experiments in the Derne Gallery.* (From *Glückauf*.) (57) Nov. 10.
Extra-Lateral Right—Shall it be Abolished? William E. Colby. (103) Nov. 11.
Estimating Construction Costs. Frederick W. Foote. (16) Nov. 11.
Ore-Sampling Conditions in the West.* T. R. Woodbridge. (Abstract from *Technical Paper 86* of U. S. Bureau of Mines.) (103) Nov. 11.
Old Ohio Mine Without Railroad Connections.* Wilbur G. Burroughs. (45) Nov. 11.
Britannia Mine and Mill.* T. A. Rickard. (103) Nov. 11.
Reducing Air-Drill Repair Costs.* Frank Ayer. (16) Nov. 11.
Most Powerful Gold Dredge Afloat.* Robert Sibley. (111) Nov. 11.
Comparative Costs of Mine Haulage by Horses and Compressed Air. (From *Compressed Air Magazine*.) (86) Nov. 15.
Pithead Baths in Some Foreign Collieries.* John Y. Dunlop. (101) Nov. 17.
G-E Miners' Lamp Approved by the U. S. Bureau of Mines.* (82) Nov. 18.
Efficiency with New Mine Cars.* Fred M. Heidelberg. (16) Nov. 18.
Use of Signboards and Signals in Mines. D. J. Parker and E. Steidle. (82) Nov. 18.
Flat Top Coal-Washing Plant.* J. G. Hanlin. (45) Nov. 18.
Salt-Wells of Tzuliutsing. H. K. Richardson. (19) Nov. 18.
Zinc Mines of Tonkin (China). (16) Nov. 18.
The Cost of Coal. George Otis Smith and C. E. Lesher. (Paper read before the Am. Mining Congress.) (105) Dec. 1.
Electric Shovel at Granby Mine, Phoenix, B. C.* C. M. Campbell. (16) Dec. 2.
Testing Mine Rescue Apparatus.* C. E. Pettibone. (Abstract of paper read before National Safety Council.) (16) Dec. 2; (45) Nov. 25.
Valuation of Bedded Mineral Land. F. A. Guignon. (16) Dec. 2.
Le Charbon et le Fer en Hollande. (33) Nov. 4.
La Production du Tungsten en Europe. (33) Nov. 11.

Miscellaneous.

The Checking of Estimates and Costs. (23) Serial beginning Sept. 1.
Engineering Society—Its Past, Present and Future Activities. Ernest McCullough. (4) Oct.
The Principle of Similitude in Engineering Design. T. E. Stanton. (Paper read before Section G of the British Assoc.) (12) Oct. 20.
Deterioration of Leather Used in Gas Meters. M. C. Lamb. (From *Journal* of Soc. of Chemical Industry.) (66) Oct. 24.
Administration: Its Principles and Their Application. Wm. Hemphill Bell. (3) Nov.
The Ratio of the Specific Heats and the Coefficient of Viscosity of Natural Gas from Typical Fields. Robert F. Earhart. (Abstract.) (55) Nov.

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Accurate Appraisals by Short Methods. John G. Morse. (Abstract.) (55) Nov.
Productive Capacity a Measure of Value of an Industrial Property.* H. L. Gantt. (Abstract.) (55) Nov.
The Sales Engineer and his Relation to Production and Machine Design.* Arthur J. Baker. (55) Nov.
Continuous Inventories: Their Preparation and Value. Harry E. Carver. (42) Nov.
Effect of Recent Decisions on the Work of Inventory and Appraisal. (42) Nov.
Public Service Regulation. J. L. Schley. (100) Nov.
Growth and Depreciation.* Julian Loebenstein. (42) Nov.
Development of Our Potash Industry. F. M. de Beers. (Paper read before the Am. Meat Packers' Assoc.) (105) Nov. 1.
Cracking of Paraffin Base Oils; Time Factor and the Temperature Factor Under Pressure. Gustav Egloff, Thomas Twomey, and Robert J. Moore. (105) Nov. 1.
Population Studies by Moore Expectancy Curve.* George Holmes Moore. (13) Nov. 2.
Obsolescence in Appraisals for Rate Making. C. C. Harshman. (13) Nov. 2.
Works Organization.* A. D. C. Parsons, Edwin L. Orde, and G. H. Tweddell. (Paper read before the North-east Coast Institution of Engrs. and Shipbuilders.) (47) Serial beginning Oct. 27; (73) Nov. 3.
Making a Cost Profile.* P. L. Mathews. (45) Nov. 4.
Specifications and Standard Definitions.* H. B. Twyford. (17) Nov. 4.
Is Utility Regulation on the Right Basis? J. D. Galloway. (14) Nov. 4.
Functional *versus* Geographical Plan of Organization.* T. L. Hinckley. (96) Nov. 9.
X-Ray Spectrum: How They Are Formed and Consequences of the Present Theory.* A. W. Hull. (19) Nov. 11.
Process of the Organic Chemical Industry as Used in the Manufacture of Intermediate Products.* A. H. Ney and D. J. Van Marle. (105) Nov. 15.
Principles of Industrial Organization.* H. N. Stronck. (105) Nov. 15.
Guayule and Industrial Preparedness. Andrew H. King. (105) Nov. 15.
Electric *vs.* Steam Logging.* W. D. Peaslee. (Paper read before the Pacific Coast Logging Congress.) (111) Nov. 18.
U. S. Office of Public Roads Reorganized. (Organization.)* L. W. Page. (14) Nov. 18.
Protecto Ammonia Helmet. (64) Nov. 21.
Diagram for Obtaining Number Feet B. M. in Various Timbers.* W. R. Roof. (86) Nov. 22.
Valuation of Industrial Properties *vs.* Valuation of Industrial Methods. Walter N. Polakov. (Abstract.) (55) Dec.
Relation between Perpetual Inventory Value and Appraisal Value. Charles Piez. (Abstract.) (55) Dec.
Flow of Air and Steam Through Orifices.* Herbert B. Reynolds. (Abstract.) (55) Dec.
Spontaneous Ignition Studied by Means of Photographic Plates.* Frederick J. Hoxie. (Abstract.) (55) Dec.
Inadequacy and Inconsistency of Some Common Chemical Terms. Carl Hering (105) Dec. 1.
Manufacture of Potassium Chlorate. Anson G. Betts. (105) Dec. 1.
Influence de la Pression sur l'Inflammation Electrique du Méthane. (33) Oct. 21.
Formule Générale de Salaires Modernes.* (33) Nov. 4.
Moyen de Developper en France l'Industrie Chimique: Creation de Laboratoires de Recherches Industrielles. (33) Nov. 4.
L'Organizatión du Travail dans les Usines Automobiles Ford aux Etats-Unis.* (33) Nov. 11.

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Economical Snow Removal: The Sutcliffe Plough.* (104) Nov. 10.
Some Details of New Street Lighting System of Pocatello, Idaho.* (86) Nov. 22.
Park Grading by Day Labor.* (13) Nov. 23.
Ideen-Wettbewerb für einem Bebauungsplan der Gemeinde Bözingen.* (107) Nov. 4.

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Atchison, Topeka and Santa Fe Steel-End Box Wagons.* (23) Sept. 1.
New 2-10-2 Type Locomotives.* (N. Y., Ontario & Western Ry.) (23) Sept. 1.
Completing the Mount Royal Tunnel into Montreal.* (23) Sept. 1.
Refrigerator Cars for the Santa Fe.* (23) Sept. 8.
4-Cylinder Express Locomotive—Norwegian State Railways.* (23) Sept. 8.
Equipment of Signal Boxes.* (23) Sept. 8.
Practical Method for the Adjustment of Curves.* W. F. Rench. (23) Sept. 15.
Superheater Goods Locomotive—Great Eastern Railway.* (23) Sept. 15.
New Alternating-Current Signal Installation on the Grand Trunk Railway.* (23) Sept. 15.

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Pulverized Fuel for Locomotives.* J. E. Muhlfeld. (23) Sept. 22; (55) Dec.
Baldwin Narrow Gauge Locomotives.* (23) Sept. 22.
The "Intensifore" Lubricator for Locomotives.* (23) Sept. 22.
Train Control on the East Indian Railway.* (23) Sept. 22.
Modern Terminal Passenger Yard.* (23) Sept. 22.
Canadian Northern Steel Frame Passenger Cars.* (23) Sept. 29.
Four Cylinder 4-8-0 Type Locomotive, Norwegian State Railways.* (23) Sept. 29.
American Type Two-Cylinder Locomotives on the Eastern Railway of France.* (21) Oct.
The Montreal Locomotive Works, Ltd.* (23) Oct. 6.
Cab Signals and Automatic Stops on the Western Pacific Railroad.* (23) Oct. 6.
Electrification of the Chicago, Milwaukee & St. Paul Railway.* (23) Oct. 13.
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PAPERS AND DISCUSSIONS

TESTS OF CONCRETE SPECIMENS IN SEA WATER, AT BOSTON NAVY YARD

By R. E. Bakenhus, M. Am. Soc. C. E.

To be Presented January 3d, 1917.

Synopsis.

This paper describes a test of twenty-four concrete specimens which were immersed in sea water for 7 years. The object of the tests was to determine the action of sea water on concrete specimens of wet and dry consistencies, of various proportions of ingredients, and of different brands of cement, as well as the effect of special compositions.

The methods of mixing, analyses of the various cements, sand, and stone, and the conditions of the test, as well as all other data having possible effect on the results, are stated in the paper. The information is given in tabular form where possible.

The specimens were examined at intervals of about one year, and record was made of their condition. The results of these observations have been tabulated, and show progressive deterioration of some of the specimens and remarkable durability of others. Recently, the specimens were examined with great care, and graded in the order of durability. These results are also tabulated. Independent tabulations are made of the various series of tests originally planned, to

Note.—These papers are issued before the date set for presentation and discussion. Correspondence is invited from those who cannot be present at the meeting, and may be sent by mail to the Secretary. Discussion, either oral or written, will be published in a subsequent number of *Proceedings*, and, when finally closed, the papers, with discussion in full, will be published in *Transactions*.

ascertain in one case the effect of wet and dry mixture, in another case the effect of rich and lean mixture, and in others the effects of special brands of cement, and of using lime, Sylvester wash, etc., with the cement.

The results are interesting, and seem to show, briefly:

(*a*) That the 1 : 1 : 2 mixture is superior to the 1 : 2½ : 4½. and that the 1 : 2½ : 4½ is, in turn, superior to the 1 : 3 : 6;

(*b*) That the wet mixtures are superior to the dry;

(*c*) That the effects of magnesia or alumina in varying proportions are not very marked, and follow no apparent law, although the two most durable specimens are those lowest in alumina content;

(*d*) That extra care in mixing produced decidedly beneficial results;

(*e*) That hydrated lime was of no benefit, but rather a detriment;

(*f*) That the addition of Sylvester wash was harmful; and

(*g*) That the addition of clay to the cement had a slightly beneficial result.

The deterioration occurred between high and low water, and was most marked at mid-tide. Above high water there was little deterioration, and the same is true, but to a less marked extent, of the concrete continually submerged.

A careful reading of the paper should be made before any of the foregoing conclusions are applied. The experiments are not sufficiently extensive to warrant drawing final conclusions in all cases, unless confirmatory evidence is available. In utilizing the results, the limitations of the tests and local conditions should be taken into account.

About 7 years have elapsed since twenty-four concrete specimens were placed in sea water at the Boston Navy Yard. The results, on careful analysis, give information of considerable value. This paper presents a résumé of the important facts in regard to the preparation of the specimens, the recorded observations at stated periods, and a tabulation and discussion of the results to date.

The various facts and observations connected with the tests are given in full, so that those who wish may study them and draw their

own conclusions. Those who are sufficiently interested may observe the specimens at the Navy Yard. In the latter part of this paper the principal results of the tests are summarized, and the conclusions of the writer are stated, without attempted explanation, however, as to the causes of the different kinds of action on the concrete specimens.

The expense of making the tests is borne entirely by the Aberthaw Construction Company, of Boston, who proposed them and entered into agreement with the Navy Department, represented by the late Fred Thompson, Civil Engineer, U. S. Navy, M. Am. Soc. C. E. The agreement (Appendix A) covers the conditions of the tests whereby the specimens were permitted to be made and exposed in the Navy Yard, all work being under the inspection of the Civil Engineer, now Public Works Officer, of the Yard, and the Navy Department having the right to observe the specimens and to use the information obtained.

Each of the twenty-four specimens is 16 ft. long and 16 in. square, weighing from 4 050 to 4 350 lb. They are hung on Pier 9, at the Boston Navy Yard, in such a manner that the lower ends are continually immersed, the upper ends but rarely immersed, and the center portions are subject to alternate action of the air and salt water due to the 10-ft. tides.

The specimens were originally suspended, in February, 1909, from the old Pier 9, but, as this was rebuilt, they were moved on December 5th, 1911, to Pier 8, east side. Later, it became necessary to renew the supporting bridles, and, on September 19th and 20th, 1912, the specimens were removed and leaned against the quay wall and on October 30th and 31st, 1912, were moved to the newly constructed Pier 9. The piers are of open wooden pile construction, giving the sea water a free flow. About April, 1914, a pipe line for furnishing fuel oil to naval vessels was placed on Pier 9, and since then the concrete has become coated with a thin film of fuel oil. The sea water is that of Boston Harbor, analyses of which will be given. Fig. 1 is reproduced from a photograph showing the specimens as suspended from Pier 9 in April, 1916.

The specimens were lifted out of the water on December 9th and 10th, 1913, for the purpose of photographing them and were immediately replaced.

The following description of the manufacture of the specimens is taken from the file copy of the records made at the time:

"The specimens were made on the first floor of Building No. 107 at the Navy Yard, which was kept above freezing point but yet not very warm. The feeding chute was removed, and materials were shoveled directly from the floor to the mouth of the mixer, which was about 3 ft. above. The materials were dumped into a water-tight mortar box, from which they were shoveled into wheel-barrows and wheeled to forms made of plank a short distance away. The specimens were cast in a horizontal position. Embedded in each for its full length and projecting from the end (forming a loop) was a ⅝-in. square twisted steel bar, bent in its middle (embedded near diagonal corners), to give the specimens stiffness, so that they could be handled without breaking. There was also embedded in the upper end of each specimen for a depth of 8 ft. a steel pipe, 2½ in. outside diameter. This was used merely to core a hole and, after the specimens were set, was removed in the following manner: Before placing, it was coated on the outside with paraffin. After the specimens were set, live steam was turned into the pipe, which then was removed easily and quickly. In the very top of each specimen was embedded a 3-in. pipe which was threaded and capped. The object in coring this hole and capping it was to see if sea water percolated into the center of specimens. (This was used afterward for fastening hooks supporting the specimens when the loops had rusted away.)

"The sand and stone were measured in accurately made frames. In measuring they rested on a perfectly smooth hardwood floor. The materials were struck smooth on top with a straight-edge. The frames were made deep in order to avoid the large errors in volume which occur when frames are very shallow and cover a large area. The sand and stone were completely fed into the mixer first; then cement was shoveled in, which took about 1 min. After ½ min., water was added with pails, being accurately weighed. This took about 1 min. to add. In every case, in as near 2 min. as possible after the first water was added, the batch was dumped from the mixer. It took from 15 to 18 min. to place a batch entirely in the forms, into which it was thoroughly spaded and tamped. The workmanship was intended to reproduce as nearly as possible actual commercial conditions.

"The first nine specimens, which were made from a standard average composition Portland cement, were made by mixing together equal parts of Vulcanite, Alpha, and Giant. These were thoroughly mixed in the mortar box and then repacked by weight. The cement free from iron was Blanc Stainless; the commercial Portland high in alumina was Atlas; the commercial Portland cement low in alumina, was a mixture of equal parts of Lehigh and Helderberg; the iron ore cement practically free from alumina was Hermmoor Erz German Portland cement; and the slag cement was Universal.

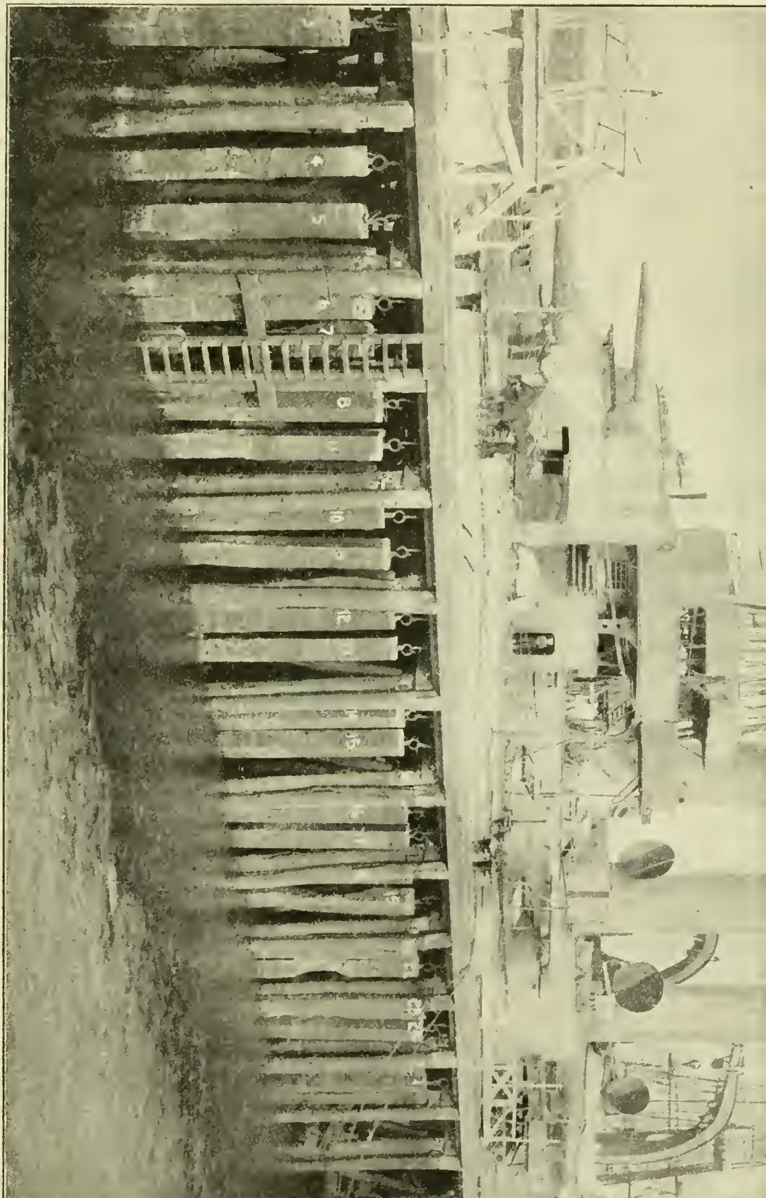


FIG. 1.—CONCRETE SPECIMENS SUSPENDED FROM PIER 9, BOSTON NAVY YARD.

"The stone was broken trap rock from the quarries of E. Burnett, Franklin Park ledge, Malden, Mass. A cubic foot of stone weighed 90.24 lb. Determination of voids in stone was 50 per cent. The stone passed a 1¼-in. ring, with the dust screened out.

"The sand was clean and sharp, a little finer than usual, from the bank of P. O'Riorden, at South Acton, Mass. Dry, it weighed 97.18 lb. per cu. ft. Determination of voids in the dry sand was 34.2 per cent. As used in the work, the sand contained 4.6% of moisture by weight.

"With the above determined percentage of voids, the mixture, nominally 1 : 2 : 4 but proportioned so as to have 10% excess of cement over the voids in sand, and 10% of mortar over voids in the stone, was actually proportioned 1 : 2½ : 4½.

"The specimens remained in the building for about 5 weeks. They were then loaded on flat cars and moved to Pier 9 in the Yard, and were hung from the cap log, as shown by Fig. 1. During the loading of the specimens, they were calipered in each direction close to each end and every 2 ft. along their length. Their length was also measured and the length to which the core pipe was embedded. Before hanging from the pier, they were weighed on platform scales.

"In the process of moving and setting, Specimen No. 22 was cracked clear through, at about 6 ft. from the lower end, and Specimen No. 23 had a very small crack on the face, about the middle.

"From concrete left over from filling the forms, fifteen 8-in. cubes were made of mix similar to Specimen No. 3, and fifteen others were mixed similar to Specimen No. 9. These were put in a box for convenience in keeping them together; one-third were immersed permanently; one-third were supported at half-tide; and one-third were kept in a dry place exposed to the weather."

The analyses of sand and stone made by Mr. Herbert L. Sherman for the Aberthaw Construction Company, as given in Table 1, apply to all the specimens.

TABLE 1.—Analyses of Sand and Stone Used in all Specimens.

Bank Sand.

Fineness, passing sieves, by weights.

No. 100	No. 50	No. 30	No. 20	No. 16	No. 10	No. 8	No. 6	¼-inch.
4.8%	24.0%	52.0%	73.4%	86.4%	91.0%	93.4%	96.1%	100.0%

Voids by volume.............................. 34.2 per cent.
Moisture.. 4.6 " "

The sand is very fine, but is clean and of good quality.

TABLE 1.—(*Continued*).

BROKEN STONE.

Fineness, passing sieves, by weights.

⅛-in.	3/16-in.	¼-in.	⅜-in.	½-in.	¾-in.	1-in.	1½-in.
0.25%	0.50%	1.75%	9.75%	25.25%	53.0%	80.75%	100.0%

Voids by volume........................... 50.0 per cent.
The stone is a broken trap rock of very good quality.

Table 2 shows the analyses of the various cements used in preparing the specimens.

TABLE 2.—
By Mr. Herbert

Brand	Vulcanite, Alpha, Giant, Mixed equally. (Average alumina.)	Lehigh, Helderberg, Mixed equally. (Low alumina.)	Atlas. (High alumina.)	Blanc. (White Portland).
Percentage passing No. 100 sieve	94.8	93.8	94.2	94.4
Percentage passing No. 200 sieve	79.6	78.8	76.2	75.0
Initial set	1 hr. 35 min.	2 hr. 10 min.	1 hr. 45 min.	0 hr. 25 min.
Final set	4 hr. 45 min.	5 hr. 0 min.	4 hr. 10 min.	3 hr. 20 min.
Percentage of water	22	22	22	23
24 hr. neat, pounds tension	313	312	342	277
7 days " " "	660	636	677	549
28 days " " "	755	741	744	726
48 hr. moist air, pounds, tension	....	....	....	....
Percentage of water	22	22	22	23
7 days, Ottawa sand, 1:3	264	184	272	191
28 " " " 1:3	360	312	304	319
Percentage of water	9	9	9	9
7 days, Bank sand, 1:3	217	133	168	159
28 " " " 1:3	318	271	211	218
Percentage of water	10	10	10	10
Loss on ignition, Percentage	0.96	1.04	1.06	1.69
Silica (SiO_2), "	22.08	23.40	21.46	24.58
Alumina (Al_2O_3) "	7.21	5.61	8.50	8.22
Iron oxide (Fe_2O_3) "	2.57	2.37	2.44	0.29
Lime (CaO) "	62.60	62.90	61.64	62.70
Magnesia (MgO) "	2.74	2.51	2.58	1.11
Sulph. anhydride (SO_3), Percentage	1.56	1.53	1.75	1.32
Specimen numbers	1 to 9, inclusive. 20 to 24, inclusive.	14 and 15	12 and 13	10 and 11

The analysis of the water used in mixing the specimens is indicated clearly enough by the analysis of tap water at the time, as stated in the report of the Metropolitan Water and Sewerage Board. It is as follows:

Analyses of Water (Report of Metropolitan Water and Sewerage Board, 1909, p. 232.) Water taken from tap at State House, Boston, Mass., February 1st, 1909.

Parts per 100 000.

Appearance:	Turbidity very slight. Sediment, slight.
Color:	Platinum standard. 20.
Odor:	Cold: Decided geranium, Asterionella.
	Hot: " " "

Residue on evaporation: Total 3.5. Loss on ignition, 1.2.

CEMENT ANALYSES.

L. Sherman.

Univer-sal. (Slag.)	Hermmoor Erz. (Iron ore.)	Vulcanite... Alpha....... Giant....... Mixed equally, 95% Pulv. clay, 5%.	Vulcanite.. Alpha..... Giant...... Mixed equally, 90% Hyd. lime, 10%.	Vulcanite.. Alpha...... Giant...... Mixed equally. Mixed sea water,
95.6	95.8	Clay 99.0	Hyd. lime 95.2	....
78.8	82.6	Clay 58.0	Hyd. lime 88.2	....
35 min.	45 min.	1 hr. 40 min.	10 min.	1 hr. 15 min.
2 hr.	26 hr.	4 hr. 40 min.	4 hr.	4 hr. 30 min.
22	22	22	25	22
315	0.0 *	248	276	339
608	441	723	566	690
717	641	762	717	735
....	223	....	....	....
22	22	22	25	22
194	132	211	148	204
258	234	255	216	....
9	10	9	9	9
166	108	169	117	223
181	174	222	182	....
10	11	10	10	10
2.82	0.91	0.96	20.24 (18.73 water)	
20.42	24.28	22.08	1.32 and insoluble matter	
8.04	0.94	7.21	Al_2O_3 / Fe_2O_3 0.68	
3.04	9.08	2.57		
62.16	62.12	62.60	(Hydrated lime.) 45.88	
1.63	0.43	2.74	31.62	
1.73	1.75	1.56	CaO_2 1.51	
18 and 19	16 and 17	24	22	21

* No strength on 24-hr. neat test; cement did not have hard set.

Ammonia:	Free 0.0016	
	Albuminoid, Total 0.0128	Dissolved 0.0108; Suspended 0.0020
Chlorine:	0.38	
Nitrogen: as	Nitrates, 0.0060; as Nitrites, 0.0000.	
Oxygen consumed:	0.17	
Hardness:	1.7	

The chemical analysis, by A. L. Babbitt, Navy Yard Chemist, of the salt water of Boston Harbor in which the specimens are immersed, at low tide, is as follows (Samples of sea water taken February 1st. 1916, from slip between Piers 8 and 9, for use in report of concrete test specimens):

Specific gravity	1.0220	
Total solids	32 100	parts per million.
Silica	1.6	" " "
Iron and aluminum oxides	3.6	" " "
Calcium	365.9	" " "
Magnesium	1 138.7	" " "
Sodium	9 163.0	" " "
Potassium	508.6	" " "
Sulphate radical (SO_4)	2 232.2	" " "
Chlorine	16 350.0	" " "

Hypothetical Combinations.

	Parts per million.	Grains per U. S. gallon.
Silica	1.6	0.10
Iron and aluminum oxides	3.6	0.20
Calcium carbonate	780.4	45.5
Calcium sulphate	181.2	10.6
Magnesium sulphate	2 637.7	153.8
Magnesium chloride	2 370.1	138.2
Sodium chloride	23 290.5	1 357.8
Potassium chloride	966.3	56.3

And at high tide as follows:

Specific gravity	1.0217	
Total solids	31 820.	parts per million.
Silica	1.2	" " "

Iron and aluminum oxides.....	3.6	parts per million.
Calcium	354.5	" " "
Magnesium	1 117.1	" " "
Sodium	9 041.0	" " "
Potassium	503.4	" " "
Sulphate radical (SO_4)........	2 286.6	" " "
Chlorine	15 980.0	" " "

Hypothetical Combinations.

	Parts per million.	Grains per U. S. gallon.
Silica	1.2	0.07
Iron and aluminum oxides.....	3.6	0.20
Calcium carbonate.............	844.2	49.2
Calcium sulphate..............	39.6	2.3
Magnesium sulphate...........	2 831.5	165.1
Magnesium chloride............	2 132.1	124.3
Sodium chloride...............	22 980.4	1 339.8
Potassium chloride.............	956.4	55.9

Table 3 shows the scheme of the tests. For the purpose of this report, they have been arranged in eleven series, according to the cement used. Those in series II to XI, inclusive, in every case have parallel tests in Series I, which is the principal one.

Table 3-*A* gives, for each specimen:

(*a*) The important dates;

(*b*) The materials of which made;

(*c*) The proportions.

The percentage of water used, as given in the tables, is not an absolute guide to the quantity in the concrete, because, during a portion of the tests, a snow storm caused the sand and stone to become wetter initially.

The progressive condition of the specimens is shown in Table 4 where the information is collated for convenient reference.

The observations as to condition of the specimens were made at various times by Mr. E. S. Phelps, DeWitt C. Webb, M. Am. Soc. C. E., Civil Engineer, U. S. Navy, and by the writer.

TABLE 3.—

Proportions.	Series I. Mixed Cement. Average Alumina. Al_2O_3 7.21% MgO 2.74%		Series II. Blanc Cement. Al_2O_3 8.22% MgO 1.11%		Series III. Atlas Cement. Al_2O_3 8.5% MgO 2.58%		Series IV. Helderberg and Lehigh Cement. Al_2O_3 5.61% MgO 2.51%		Series V. Hermmoor Erz Iron Ore Cement. Al_2O_3 0.94% MgO 0.43%	
	No. of Specimen.	Water, in pounds per cubic foot.	No.	Water.	No.	Water.	No.	Water.	No.	Water.
1 : 1 : 2	1	Dry 9.3								
1 : 1 : 2	2	Wet 10.4	10	Wet 10.2	12	Wet 11.0	14	Wet 11.7	16	Wet 11.1
1 : 1 : 2	3	Very wet 12.5								
1 : 2½ : 4½	4	Very dry 5.9								
1 : 2½ : 4½	5	Wet 7.1								
1 : 2½ : 4½	6	Very wet 12.2								
1 : 3 : 6	7	Very dry 5.8								
1 : 3 : 6	8	Wet 7.7								
1 : 3 : 6	9	Very wet 11.3	11	Very wet 12.1	13	Very wet 11.3	15	Very wet 11.7	17	Very wet 10.2

NOTE.—The weight of water, in pounds per cubic foot, takes

A very careful examination, by three experienced observers, was made in April, 1914, at low tide, of all the specimens, and they were graded and classified on the spot in accordance with their condition at the time. The estimates of grade and class were on the basis of durability or serviceability of the concrete, as if it were in actual service. The examination was made after the specimens had been in the water 5 years, since which time there have been no changes of note. The various classes, especially the upper ones, grade into one another with definite, but without particularly strong, dividing lines. The specimens in each class are arranged from left to right in the order of durability.

The following is a copy of the report on classifying and grading the specimens:

"APRIL 1ST, 1914.

"Specimens graded largely as to condition at point of maximum deterioration.

"Specimens in order of durability.

"Elevation of tide, 1 ft. above mean low water at time of examination.

SCHEME OF TESTS.

Series VI, Universal Slag Cement. Al_2O_3 8.04% MgO 1.63%		Series VII, like Series I, Concrete extra well mixed. Al_2O_3 7.21% MgO 2.74%		Series VIII, like Series I, using sea water.		Series IX, like Series I, with lime.		Series X, like Series I, with Sylvester Solution.		Series XI, like Series I, with 5% Clay.		
No.	Water.	No.	Water.	No.	Water.	No.	Water.	No.	Water.	No.	Water.	
18	Wet 11.5											Series XII.
19	Very wet 13.03	20	Very wet 9.7	21	Very wet 9.7	22	Very wet 10.7	23	Very wet 9.6	24	Very wet 9.5	Series XIII.

no account of moisture in the ingredients before mixing.

Class 1: Perfect condition; No. 14.

Class 2: Nearly perfect condition; Nos. 3, 16.

Class 3: Very fine condition, but with slight deterioration; Nos. 18, 12, 10, 2.

Class 4: Very good condition, but with some deterioration; Nos. 6, 5.

Class 5: Good condition, but with deterioration apparent; Nos. 15, 20, 24, 17, 1.

Class 6: Fair condition; deterioration apparent; concrete soft in spots near low-water mark; Nos. 9, 11, 13.

Class 7: Poor condition; decided deterioration; concrete shows deterioration at low water; Nos. 4, 8.

Class 8: Very bad condition; concrete disintegrated and badly eroded above low water; Nos. 22, 19, 23.

Class 9: Exceedingly bad condition; concrete totally disintegrated and eroded above low water line, No. 7."

The following specimens showed deterioration between the 1914 and 1916 inspections, arranged in the order of greatest deterioration: Nos. 22, 19, 23, 7, 11, 4. The remaining specimens show no noticeable

TABLE 3-*A*.—DATA RELATING

No. of specimen.	Kind of mixture.	DATES: (ALL IN 1909.) Of mixing.	Forms removed.	Immersed.	Kinds of cement used.	Proportions.	No. of batches.
1	Dry.	Jan. 8	Jan. 9	Mar. 1	Equal parts of Vulcanite, Alpha, and Giant.	1 : 1 : 2	3
2	Plastic.	Jan. 8	Jan. 11	Mar. 1	Equal parts of Vulcanite, Alpha, and Giant.	1 : 1 : 2	3
3	Very wet.	Jan. 9	Jan. 11	Mar. 1	Equal parts of Vulcanite, Alpha, and Giant.	1 : 1 : 2	3
4	Dry.	Jan. 9	Jan. 11	Mar. 1	Equal parts of Vulcanite, Alpha, and Giant.	1 : 2½ : 4½	3
5	Plastic.	Jan. 9	Jan. 11	Feb. 23	Equal parts of Vulcanite, Alpha, and Giant.	1 : 2½ : 4½	3
6	Very wet.	Jan. 9	Jan. 11	Feb. 23	Equal parts of Vulcanite, Alpha, and Giant.	1 : 2½ : 4½	3
7	Quite dry.	Jan. 11	Jan. 13	Feb. 27	Equal parts of Vulcanite, Alpha, and Giant.	1 : 3 : 6	4
8	Plastic.	Jan. 11	Jan. 13	Feb. 23	Equal parts of Vulcanite, Alpha, and Giant.	1 : 3 : 6	4
9	Wet.	Jan. 11	Jan. 13	Feb. 23	Equal parts of Vulcanite, Alpha, and Giant.	1 : 3 : 6	4
10	Wet.	Jan. 12	Jan. 14	Feb. 27	Blanc (white Portland).	1 : 1 : 2	3
11	Wet.	Jan. 12	Jan. 14	Feb. 27	Blanc (white Portland).	1 : 3 : 6	3¾
12	Wet.	Jan. 12	Jan. 14	Feb. 27	Atlas, high in alumina.	1 : 1 : 2	3
13	Wet.	Jan. 12	Jan. 14	Feb. 27	Atlas, high in alumina.	1 : 3 : 6	4
14	Wet.	Jan. 13	Jan. 15	Feb. 23	Equal parts of Helderberg and Lehigh.	1 : 1 : 2	3
15	Wet.	Jan. 13	Jan. 15	Feb. 27	Equal parts of Helderberg and Lehigh.	1 : 3 : 6	4
16	Wet.	Jan. 15	Jan. 18	Feb. 23	Iron ore (Hermmoor Erz) (German).	1 : 1 : 2	3

TO MIXTURE OF CONCRETE.

Weights (All in Pounds): Of water in batches.	Total of water.	Total of cement.	Of specimen.	Per cubic foot.	Of water per cubic foot.	Volume of concrete, in cubic feet.	Percentage of water to total weight.	Percentage of water to cement, by weight.	Condition of concrete after mixing.
88, 80, 80	248	1128	4057.5	152.1	9.3	26.68	6.1	22	Water glistened, but did not spatter or quake.
107, 93, 95	295	1128	4267.5	151.06	10.4	28.25	6.9	25.2	No water spotted surface from tamping, but a little movement could be seen 12 in. from tamp.
125, 150, 150	425	1128	4197.5	145.04	12.5	28.044	8.4	37.6	Soft enough to run out of overturned wheel-barrow, but would not flow like syrup. First two batches required a little tamping. Third batch showed quake when tamping.
58, 55, 52	165	1128	4122.5	145.82	5.9	28.267	4.0	14.6	No free water, but surface was moist. Shoveled from barrow and every shovelful tamped by two men.
66, 63, 66	195	1128	4127.5	150.3	7.1	27.46	4.7	17.2	Top surface quite wet. Just barely spattered, and quaked a very little at a few inches from tamp.
125, 115, 105	345	1128	4297.5	152.2	12.2	28.225	8.0	31.4	Nothing in report.
47, 45, 45, 45	182	1504	4097.5	142.5	5.8	28.74	4.1	12.1	When filled glistened at a point about 4 ft. from end. Did not quake.
60, 60, 60, 60	240	1504	4202.5	146.58	7.7	28.67	5.7	16	Moderate tamping showed quaking; spots of water on surface.
88, 85, 85, 85	343	1504	4162.5	145.4	11.3	28.62	7.8	22.8	Forms filled and water ran off, spattered and quaked.
95, 100, 110	305	1128	4267.5	142.1	10.2	30.03	7.1	26.2	Quaked when tamped lightly. Quite wet when dumped. Cement acted quickly.
100, 100, 93, 60	353	1455	4297.5	146.20	12.1	29.39	8.5	24.2	Flowed off shovel easily. Showed quaking, and spattered from light tamping. Concrete when tamped flowed water off form. This concrete set before that of No. 10 specimen made previously.
105, 110, 110	325	1128	4172.5	145.9	11.0	28.58	7.5	28.8	Quaked with light tamping. Spotted on surface.
95, 95, 95, 60	345	1504	4047.5	142.8	11.3	28.34	7.9	25.1	Flowed off shovel easily. Tamping showed quaking. Spattered when tamped hard. Surface glazed. Light tamping showed quakes.
110, 110, 110	330	1128	4077.50	144.2	10.7	28.27	8.1	29.1	Quakes with light tamping. Spattered and showed water on surface.
95, 95, 95, 50	335	1504	4072.50	142.7	11.7	28.52	8.2	22.1	Showed quaking, light tamping. Surface glistens.
105, 105, 105	315	1134	4237.5	149.6	11.1	28.32	7.4	29.2	When leveled off showed oily streaks in water on top. Very dark, more like black mud mixture. Very oily surface. Showed quake in light tamping. Very soft after 24 hours' set; finger nail made impression.

TABLE 3-*A*.—

No. of specimen.	Kind of mixture.	Dates: (All in 1909.) Of mixing.	Forms removed.	Immersed.	Kinds of cement used.	Proportions.	No. of batches.
17	Wet.	Jan. 15	Jan. 18	Feb. 27	Iron ore (Hermmoor Erz) (German).	1 : 3 : 6	3¾
18	Wet.	Jan. 13	Jan. 15	Feb. 27	Universal (slag).	1 : 1 : 2	3
19	Wet.	Jan. 13	Jan. 15	Feb. 23	Universal (slag).	1 : 3 : 6	3¾
20	Quite wet.	Jan. 14	Jan. 16	Feb. 23	Vulcanite, Alpha, and Giant, mixed.	1 : 3 : 6	3¾
21	Wet. (Sea water.)	Jan. 14	Jan. 16	Feb. 23	Vulcanite, Alpha, and Giant, mixed.	1 : 3 : 6	3¾
22	Wet. (Lime.)	Jan. 16	Jan. 18	Feb. 23	Vulcanite, Alpha, and Giant, with one-tenth hydrated lime.	1 : 3 : 6	3¾
23	Wet. (Sylvester solution.)	Jan. 16	Jan. 18	Feb. 23	Vulcanite, Alpha, and Giant, mixed.	1 : 3 : 6	3¾
24	Wet. (Clay.)	Jan. 16	Jan. 18	Feb. 23	Vulcanite, Alpha, and Giant, mixed with pulv. clay.	1 cement : $\frac{1}{20}$ pulv. clay : 3 sand : 6 stone.	3¾

deterioration between 1914 and 1916. It is to be noted that all those that have deteriorated are in the lowest classes as to durability. Careful consideration showed that the classification made in 1914 need not be changed.

All specimens since 1914 have become coated with a fine layer of crude fuel oil between extreme high and low waters. This coating hides many of the minor defects in the specimens. The oil comes from the outlets placed on Pier 9 for fueling naval vessels.

The report of April, 1914, on the durability of the concrete, forms the basis for all the analyses of the results and for all the conclusions drawn. A tabulation and a discussion of results is offered in the following pages. Reference is made particularly to Table 3, showing the scheme of the tests and the division of the tests into thirteen series, each devised to show the effect of some particular condition, material,

(Continued).

Weights (All in Pounds):						Volume of concrete, in cubic feet.	Percentage of water to total weight.	Percentage of water to cement, by weight.	Condition of concrete after mixing.
Of water in batches.	Total of water.	Total of cement.	Of specimen.	Per cubic foot.	Of water per cubic foot.				
80, 80, 80, 53	293	1417	4172.5	145.9	10.2	28.59	7.0	20.8	Water showed on oily surface. Quaked on tamping. After 3 days showed a crust on surface.
110, 110, 110	330	1128	4162.5	145.6	11.5	28.58	7.9	29.2	Quaked with light tamping. Very dark in color.
100, 100, 100, 70	370	1410	4072.5	143.3	13.3	28.43	8.6	25.6	Quaked from light tamping. Showed water on surface, not enough to spatter from tamping.
75, 75, 75, 50	275	1410	4112.5	145.5	9.7	28.26	6.7	19.5	Showed quaking and spattered when spading sides. Water flowed over surface and down sides of forms.
75, 75, 75, 50	275	1410	4147.5	147.0	9.7	28.21	6.6	19.5	Showed quake; water flowed over surface.
90, 95, 90, 50	325	1410	4172.5	146.7	10.7	28.43	7.3	22.7	Showed quake on light tamping; also spattered. Specimen cracked in center.
80, 80, 85, 53	298	1410	3997.5	137.9	9.6	28.97	7.0	21.2	Quaked and spattered when tamping. Very fine cracks near middle.
75, 75, 75, 50	275	1410	4097.5	151.6	9.5	26.97	6.2	19.5	Showed quaking, and spattered from light tamping.

or process. The scheme of tests is as planned by those who originally laid them out; the table is devised for the purpose of this paper.

The following important results are shown by an examination of Table 5:

(*a*) The effect of proportions of materials is the most marked phenomenon developed in the tests.

(*b*) In every instance the specimen richer in cement is more durable than the corresponding leaner specimen, which is shown in detail by referring to Table 3 in connection with Table 5, as follows:

No. 1 is better than No. 4 which in turn is better than No. 7.
" 2 " " " " 5 " " " " " " " 8.
" 3 " " " " 6 " " " " " " " 9.
" 10 " " " " 11

TABLE 4.—(*Continued.*)

February, 1909.	March, 1910.	March, 1911.	June, 1912.	November, 1912.	December, 1913.	April, 1914.	January, 1916.
14	No action.	No action.	No action.	No action.	No action.	No action.	No action.
15	Fair; slight action on front.	No action, except slightly rough on face.	Back slightly flaked.	Slight deterioration, face and side.	Faces slightly marked.	Concrete slightly soft in spots. Face and sides pitted; slight erosion.	Concrete soft in spots. Face and sides pitted; slight erosion.
16	No action.	No action.	No action.	No action.	No action.	Very slight pitting at extreme low water.	Very slight pitting at extreme low water.
17	No action.	No action.	All sides flaked.	All sides flaked.	All sides very slightly flaked.	All sides pitted. Front badly pitted at M. L. W.	All sides pitted. Front badly pitted at M. L. W.
18	No action.	No action.	No action.	No action.	No action.	Sides perfect. Front and back slight pitting.	Sides perfect. Front and back pitted.
19	Very good. Face slightly rough.	No action, except slightly rough on face; cracked.	Face eroded. Concrete soft.	Back disintegrated; concrete very soft.	Badly flaked; concrete crumbling back 4-in. hole.	Face badly pitted; concrete soft; back eroded 4 in. deep.	Concrete soft and spongy; face pitted; sides badly eroded.
20	Very good. Face slightly rough.	No action, except slightly rough on face; cracked.	No action, except back flaked.	Slight deterioration at M. L. W.	Flaking all sides; corners worn.	Concrete fairly hard. Face eroded. Sides and back somewhat pitted.	Concrete fairly hard. Face eroded. Sides and back somewhat pitted.
21	Very good. Face slightly rough.	No action, except slightly rough on face; cracked.	Sunken.	Lost.	Lost.	Lost.	Lost.
22	Good; crack on face.	Rough on face.	Face and back eroded.	Face and sides eroded; edges broken.	Badly marked; 4-in. hole on face; concrete soft and dead.	Face eroded 6 in. over space 3 ft. Sides and back pitted. Con crete soft.	Face eroded 7 in., length 4 ft. Sides and back eroded from 1 to 3 ft. Concrete soft.
23	Cracked. Corners broken.	Cracked. Corners broken.	Face and back edges eroded.	Edges badly broken away.	Face badly flaked; edges bad.	Concrete eroded from 4 to 8 in. at M. L. W. Soft.	Concrete eroded from 5 to 8 in. deep about M. L. W. Concrete soft below M. L. W.
24	Good. Face slightly soft.	No action.	No action, except edges eroded.	Back edges worn; mortar on face deteriorated.	Face slightly marked. Edges worn.	Faces and sides pitted. Edges slightly soft on lower half Spec. Concrete fairly hard.	Faces and sides pitted Edges slightly soft on lower half. Concrete hard.

TABLE 4.—Progressive Condition of Specimens.

February, 1909.	March, 1910.	March, 1911.	June, 1912.	November, 1912.	December, 1913.	April, 1914.	January, 1916
1	Face rough.	Face rough, 1 in. deep.	Face rough, 1 in. deep.	Face eroded, 1 in. deep.	Face badly eroded.	Face badly eroded; porous spots.	Face badly eroded; some porous spots.
2	No action.	No action.	No action.	Slightly rough face; slightly porous.	Faces slightly pock-marked.	Edges slightly soft; faces practically perfect.	Edges slightly soft; faces practically perfect.
3	No action.	No action.	Sunken.	Slightly rough face; scale on back.	Face and back slightly pock-marked.	All faces very good; surface slightly pitted; slight injury to edges.	Faces very good; surface slightly pitted. Slight injury to edges.
4	Face pitted 1 in., sides less.	Face pitted 1 in., sides less.	Sunken.	Very rough face; concrete porous.	Face badly eaten; back flaked; sides rough.	Face badly eroded; little pitting and erosion.	Face badly eroded; some pitting and erosion.
5	No action.	No action.	No action.	Face slightly rough; porous spots on back.	Faces (all) pock-marked.	Some erosion on face; pitting on one side.	Some erosion on face; pitting on one side.
6	Very good. Surface soft.	No action.	No action.	Edges slightly broken.	Fine condition. Corners worn; face marked.	Edges show action. Face pitted; soft spots on back.	Edges show action. Face pitted; soft spots on back.
7	Face pitted; sides less.	Face eroded; sides good.	Considerable erosion, front and back.	Badly eroded, back and face; corners soft and crumbling.	Very poor; concrete soft and crumbling.	Very poor condition; 2½ in. in length completely gone.	Very poor condition; 5 ft. in length completely gone.
8	No action.	No action except back eroded.	Back eroded 4 in.; concrete soft.	Back disintegrated. Sides and face rough. Concrete soft.	Front and sides marked. Back 5-in. hole.	Face and sides slightly pitted. Back eroded 4 in. deep.	Face and sides slightly pitted. Back eroded 5 in. deep; rods exposed.
9	No action.	No action.	No action, except back chafed.	Edges worn. Slightly rough face.	Face marked. Edges worn.	Face badly pitted; sides and back slightly pitted.	Face badly pitted; side and back slightly pitted.
10	No action.	No action	No action.	Slightly rough face.	Face marked.	Some erosion on face; side and back slight pitting.	Some erosion on face; sides and back slight pitting.
11	No action.	No action.	No action.	Slightly rough face.	Face and sides marked.	Concrete hard, but chalky on surface. Edges soft. Face and sides very good.	Concrete chalky on surface. Edges soft. Face and sides good.
12	Very fair. Small areas on face have action noticeable.	No action, except slight roughness on face.	No action, except back slightly peeled.	Slightly rough face. Porous spots on back.	Back and face very slightly marked.	Very slight pitting on back; other faces fine.	Slight pitting on back; other faces fine.
13	Very slight action on face.	No action, except slight roughness on face.	No action, except slight erosion on back.	Slight disintegration of face.	Face marked; edge worn 2 in. deep.	Face pitted entire length; edges soft. Back slight pitting.	Face pitted entire length; edges soft. Back slight pitting.

No. 12 is better than No. 13
" 14 " " " " 15
" 16 " " " " 17
" 18 " " " " 19

(*c*) Only specimens of 1:1:2 mixture appear in the first three classes.

(*d*) The specimens of 1:2½:4½ (the next richer) mixture appear in Class 4.

(*e*) The one specimen of 1:1:2 mixture, *viz.*, No. 1, and those specimens of 1:2½:4½ mixture which fall below the others of their class, evidently do so from being mixed dry.

(*f*) The poorest specimens were of 1:3:6 mixture.

TABLE 5.—Classification of Concrete Specimens, After 5 Years of Exposure in Sea Water, in the Order of Durability, Showing the Influence of the Proportions of Material.

Analysis of Series I to VII, inclusive, Table 3.

1:1:2 mixtures marked ○
1:2½:4½ mixtures marked □
1:3:6 mixtures not marked.

Durability.	Specimen No.				
Class I...	14				
Class II...	3	16			
Class III...	18	12	10	2	
Class IV...	$\boxed{6}$	$\boxed{5}$			
Class V...	15	20	24	17	1
Class VI...	9	11	13		
Class VII...	$\boxed{4}$	8			
Class VIII...	22	19	23		
Class IX...	7				

The important effects of the quantity of water used in mixing are as follows:

(*a*) The weight of water, in pounds per cubic foot of concrete, takes no account of moisture in the ingredients before mixing.

(*b*) Specimens 1, 2, and 3 were made in order to test the effect of varying proportions of water. The results show durability—least with the dry and greatest with the very wet.

(*c*) Specimens 4, 5, and 6, also made to test the effect of varying proportions of water, show least durability with the dry and greatest with the very wet, this being slightly better than the wet.

(*d*) Specimens 7, 8, and 9 were also made to test the effect of varying proportions of water, and again show least durability with the dry and greater with the very wet specimen.

(*e*) In general, the results show that dry mixtures are of the least value, and that wet or very wet mixtures decidedly improve the durability.

TABLE 6.—CLASSIFICATION OF CONCRETE SPECIMENS, AFTER 5 YEARS OF EXPOSURE IN SEA WATER, IN THE ORDER OF DURABILITY, SHOWING THE INFLUENCE OF THE QUANTITY OF WATER USED IN MIXING.

Analysis of Series I to XIII, inclusive, Table 3.

Specimens of a dry mixture marked D.
Specimens of a wet mixture marked W.
Specimens of a plastic mixture marked P., equals wet W.
Specimens of a very dry mixture marked V. D.
Specimens of a very wet mixture marked V. W.
Pounds of water per cubic foot of concrete shown below the number.

Durability.	Specimen No.				
Class I...	W. $\frac{14}{11.7}$				
Class II...	V. W. $\frac{3}{12.5}$	W. $\frac{16}{11.1}$			
Class III...	W. $\frac{18}{11.5}$	W. $\frac{12}{11.0}$	W. $\frac{10}{10.2}$	P. $\frac{2}{10.4}$	
Class IV...	V. W. $\frac{6}{12.2}$	P. $\frac{5}{7.1}$			
Class V...	W. $\frac{15}{11.7}$	V. W. $\frac{20}{9.7}$	$\frac{24}{9.5}$	W. $\frac{17}{10.2}$	D. $\frac{1}{9.3}$
Class VI...	W. $\frac{9}{11.3}$	W. $\frac{11}{12.1}$	W. $\frac{13}{11.3}$		
Class VII...	D. $\frac{4}{5.9}$	P. $\frac{8}{7.7}$			
Class VIII...	W. $\frac{22}{10.7}$	W. $\frac{19}{13.3}$	$\frac{23}{9.6}$		
Class IX...	V. D. $\frac{7}{5.8}$				

TABLE 7.—Classification of Concrete Specimens, After 5 Years of Exposure in Sea Water, in the Order of Durability, Showing the Influence of the Quantity of Water Used in Mixing. Analysis of Series I (Table 3).

Durability.	Very wet.	Wet.	Dry.
Class I			
Class II	3		
Class III		2	
Class IV	$\boxed{6}$	$\boxed{5}$	
Class V			1
Class VI	9		
Class VII		8	$\boxed{4}$
Class VIII			
Class IX			7

Table 7 shows more clearly than Table 6 the effect of varying quantities of water used in mixing, because only those specimens are included which were devised to test this particular feature. The results were as follows:

(*a*) The bad effect of a "dry" mixture is plainly shown. In each of the three series the dry specimen is the least durable and the very wet the most durable.

(*b*) The 1 : 1 : 2 mixture is the most durable of each of the three classes of specimens, the dry, the wet, and the very wet.

(*c*) The 1 : $2\frac{1}{2}$: $4\frac{1}{2}$ mixture is more durable than the 1 : 3 : 6 in each of the three classes of specimens, the dry, the wet, and the very wet.

(*d*) Dryness of mixture has caused one of the specimens (No. 1), rich in cement, to be less durable than two (Nos. 5 and 6), with a lesser proportion of cement. Also, a dry specimen having a medium quantity of cement (No. 4) proved less durable than a wet specimen with less cement.

The following are the important results developed as shown by Table 8:

(*a*) It happens that the two most durable specimens are those lowest in alumina content, and, above a percentage of 7 in alumina content, no relation to durability is apparent.

(*b*) The relation of magnesia content to durability is not established, although it is noted that the first three specimens have a lower total magnesia content than the last three; but this condition is not borne out in Series XIII, Table 9.

(*c*) It is a curious condition that in the two best specimens the relation between the alumina content and the magnesia content is 2.2, the lowest of any.

TABLE 8.—Classification of Concrete Specimens, After 5 Years of Exposure in Sea Water, in the Order of Durability, Showing the Effects of the Alumina and Magnesia Content.

Analysis of Series XII (1:1:2 mixture), Table 3.

Order of Durability.		Al_2O_3.	MgO.	Total Al_2O_3 and MgO.	Factor Al_2O_3 divided by MgO.
Class.	No.				
I....	14	5.61%	2.51%	8.12%	2.2
II...........	16	0.94	0.43	1.37	2.2
III...........	18	8.04	1.63	9.64	4.9
	12	8.50	2.58	11.08	3.3
	10	8.22	1.11	9.33	7.4
	2	7.21	2.74	9.95	2.6

TABLE 9.—Classification of Concrete Specimens, After 5 Years of Exposure in Sea Water, in the Order of Durability, Showing the Effect of the Alumina and Magnesia Content.

Analysis of Series XIII (1: 2½: 4½ mixture), Table 3.

Order of Durability.		Al_2O_3.	MgO	Total Al_2O_3 plus MgO.	Factor Al_2O_3 divided by MgO.
Class.	No.				
V.........	15	5.61%	2.51%	8.12%	2.2
	17	0.94	0.43	1.37	2.2
VI.........	9	7.21	2.74	9.95	2.6
	11	8.22	1.11	9.33	7.4
	13	8.50	2.58	11.08	3.3
VIII.........	19	8.04	1.63	9.67	4.9

The following are the important results developed as shown by Table 9:

(*a*) It happens that the two most durable specimens, as in Table 8, are those lowest in alumina content. Again, above a per-

centage of 7 in alumina content, no definite relation to durability is apparent.

(*b*) There is no apparent relationship of magnesia content, within the limits obtained, to durability.

(*c*) It is a curious condition that in the two best specimens the relation between the alumina content and the magnesia content is 2.2, the lowest of any.

TABLE 10.—Classification of Concrete Specimens, After 5 Years of Exposure in Sea Water, in the Order of Durability, Showing the Durability of the Specimens as Related to Cement Mixtures.

Analysis of Series XII and XIII, Table 3.

Class.	Specimen No.	Cement.	Rank.
I	14	Lehigh and Helderberg mixed.	1
II	16	Hermmoor Erz	2
III	18	Universal slag	3
	12	Atlas	4
	10	Blanc	5
	2	Vulcanite, Alpha, Giant mixed	6
IV	....	....	
V	15	Lehigh and Helderberg.	1
	17	Hermmoor Erz	2
VI	9	Vulcanite, Atlas, Giant mixed	3
	11	Blanc	4
	13	Atlas	5
VII			
VIII	19	Universal slag	6

A study of the preceding tables discloses the results of tests of Series I to VI, inclusive, and of Series XII and XIII of Table 3. There remain the special series, numbered VII to XI, inclusive.

Specimen No. 20, Series VII, is like No. 9, Series I, except that greater care was used in mixing the ingredients. The notes say: "Better mixture than commercial 1 : 3 : 6." The results indicate that this caused it to appear in the class above its mate, it being the fourth specimen above it in durability. This specimen was better than any other in the whole of Series XIII except No. 15, which appears to have been favored by a low alumina cement. The extra care used in mixing showed a decidedly beneficial result.

Specimen No. 21, Series VIII, was made like No. 9, but sea water was used in mixing. Unfortunately, this specimen was lost overboard,

and could not be recovered. At the end of 2 years it was in good condition and equal to No. 9, except for some slight roughness on the face. Evidently the use of salt water did no material injury, and was not as deleterious as the use of insufficient fresh water.

Specimen No. 22, Series IX, was mixed with 10% of hydrated lime substituted for an equal quantity of cement, otherwise, it was the same as No. 9. The durability tests show it to be two classes below No. 9, or the fifth below it serially in grade. Evidently, the lime allowed an earlier and more rapid erosion. This specimen is also poorer than eight of the other ten similar specimens in series, showing conclusively, so far as one specimen can, the deleterious effects of the hydrated lime when used in concrete immersed in sea water.

Specimen No. 23, Series X, contained the same ingredients as No. 9 with the addition of Sylvester wash. The water used in mixing contained soap solution made by dissolving light colored soap in the proportion of $1\frac{1}{4}$ lb. to 15 gal. (125 lb.) of water. To each bag of cement was added 3 lb. of powdered alum. The total quantity of water in the batch was 288 lb. and of cement 5 bags. The addition of the Sylvester, according to the results of the tests, was decidedly harmful, as this specimen gave the poorest result of eleven similar ones. The concrete at the end of 5 years was in very bad condition.

Specimen No. 24, Series XI, is the same as No. 9, except that to each bag of cement there was added $4\frac{3}{4}$ lb. of clay. The clay was taken from a near-by excavation, dried, powdered, and mixed with each bag of cement. This specimen came through in good condition—better in fact than its mate, No. 9, and better than all the other specimens of a similar mixture, save only No. 15 (low alumina cement) and No. 20 (extra well-mixed concrete). There is evidence, therefore, that the addition of 5% of clay to the cement had a beneficial effect.

On September 11th, 1916, R. J. Wig, Engineer-Physicist of the Bureau of Standards, Washington, D. C., accompanied by Mr. L. R. Ferguson, representing the Association of Cement Manufacturers, visited the Boston Navy Yard in connection with studies of action of concrete in sea water. They were requested by the writer and kindly consented to examine the concrete specimens and to rate them in accordance with their condition at the time of the examination. It may be noted that the writer's rating of the specimens was made more than 2 years before. Only very minor differences in the two sets of

ratings occurred. In the specimens of greatest deterioration these differences can be explained by the changes in rate of deterioration during the 2-year period. The minor differences in the better specimens is explained by possible change in rate of deterioration or differences in judgment in rating two specimens nearly alike. The result as a whole is a very close confirmation of the original rating. The observers desired to note that their examinations of September 11th, 1916, were made on only the front faces and two sides of the specimens, as it was impossible to see the back faces without a small boat which was not available at the time.

The ratings, as made by Messrs. Wig and Ferguson, are as follows:

Group 1: Good condition, showing practically no deterioration; Nos. 14, 3, 16, 12, 10, 2.

Group 2: Satisfactory condition, showing little disintegration, but specimens are structurally sound; Nos. 6, 15, 18, 17.

Group 3: Poor condition, showing marked disintegration and, if part of a structure, in need of repair at once or at an early date; Nos. 1, 9, 5, 20; Nos. 4, 24, 11, 13.

Group 4: Bad condition and structurally unsound; Nos. 8, 23.

Group 5: Total failure; Nos. 22, 19, 7.

The bottoms of the specimens are at such an elevation that they are always submerged in sea water. The only chance for the examination of these parts of the specimen is when they are removed from their normal positions. On December 9th and 10th, 1913, the specimens were rehung from Pier 9. At that time the bottom of each specimen was examined, and no deterioration in the concrete was found to have taken place in any of the specimens.

The tops of all specimens are at such an elevation that they are very seldom submerged, and then only for a very short time. The concrete on the tops of all specimens appears to be in as good condition as when the specimens were originally constructed, and to show no deterioration, even in specimens that have eroded badly lower down. There are signs of some mechanical wear on the top edges of Specimens Nos. 7 and 22, but there is no appearance of deterioration of the concrete.

The 8-in. cubes formed at the time the larger specimens were made are now as follows: There are six 8-in. cubes on the quay wall

adjacent to Pier 9 which are exposed to the weather in a roughly constructed box. No deterioration whatever is apparent in any of these specimens. There are five 8-in. cubes in a single box placed in the dock south of Pier 9 at the elevation of mean tide. These specimens are submerged approximately 12 hours each day. All the specimens except one show a disintegration of from 1 to 3 in. on the top, and the mortar on all but one of them is soft and crumbling to the touch, having the appearance of being dead. There is one specimen, however, that shows but little deterioration; the mortar remains hard, holding the aggregate firmly together. The top and one side only of each cube is exposed, the other sides being protected by the sides of the box and the adjacent cube. The 8-in. cubes that were originally suspended so as to be entirely submerged at all times have become lost owing to the breaking of the suspension cable and no report can be made on them.

Conclusions.

The facts in connection with these tests have now been presented very fully at the risk even of over-burdening the reader with details, but with the definite purpose in mind of allowing him to draw his own conclusions in the light of his own and of others' experiences. The series of experiments has been very complete in certain directions and was conducted from the start with unusual care, and some very valuable conclusions may be established. Other conclusions of less importance may also be drawn and be established with confirmatory experiences elsewhere. Great care must be exercised in applying these conclusions in predicting results elsewhere under dissimilar conditions, and the limitations under which these tests were conducted must be borne in mind.

It is desired to acknowledge valuable assistance rendered by employees of the Public Works Department, Navy Yard, Boston, in connection with observations and the preparation of this paper, especially Mr. E. S. Phelps.

APPENDIX A.

FORM OF AGREEMENT, INCLUDING SPECIFICATIONS, FOR TEST OF CONCRETE SPECIMENS, TO BE CARRIED OUT AT THE NAVY YARD, BOSTON, MASS.

This Agreement, mutually entered into between the United States Navy Department, party of the first part, and the Aberthaw Construction Company, a corporation of Maine, having a usual place of business in Boston, party of the second part, *Witnesseth,* that the said party of the second part agrees to build at the Boston Navy Yard a series of specimens to test the durability of concrete in sea water, said specimens to be built in accordance with the specifications hereto attached.

It is agreed that the party of the second part is not to put the Government to any expense in connection with these tests, and the party of the first part does not guarantee that the piers may not be disturbed as exigencies of the Navy Yard interests may require. As these experiments are a matter of considerable interest to the Government, its representatives will endeavor to continue the tests as long as it may be possible so to do.

The party of the second part agrees that all work shall be done in the presence of a representative of the Government, and that due notice of the intention to undertake work shall be given to the Commandant and to the Civil Engineer of the Yard in time for them to make arrangements for a representative to be present.

In witness whereof, the said parties have interchangeably signed and sealed this agreement on the 28th day of December, 1908.

FRED THOMPSON,
Civil Engineer, U. S. N.
ABERTHAW CONSTRUCTION CO.,
by L. C. Wason, Pres.

SPECIFICATIONS FOR TEST SPECIMENS OF CONCRETE TO BE IMMERSED IN SEA WATER BY THE UNITED STATES NAVY DEPARTMENT, DECEMBER, 1908.

Object.—The object of these tests is to determine what the action of sea water is upon concrete, both as regards climatic conditions and chemical action. The tests are to be made as nearly as possible in conformity with usual commercial work, in order to be comparable in all respects with actual work.

How Done.—The specimens are to be built in accordance with the requirements of the Navy Department, and under their direct supervision, and in accordance with the following detailed specifications.

They are to be built in molds in the sea or in such other position as may be directed, and exposed for easy inspection and for photograph-

ing. They shall be marked so as to be easily identified, and a careful record of the materials and methods used shall be kept for each specimen.

Specimens.—The piers shall be made 16 in. square and 16 ft. long, in such a position that the lower 2 ft. shall be permanently immersed in sea water; thus it is improbable that the top will ever be immersed.

There are to be twenty-four (24) piers, as follows: In the first series of nine specimens, a standard average composition Portland cement shall be used throughout, which shall pass the standard specifications of the American Society for Testing Materials, as required by the Navy Department.

No. 1 shall be made of 1 part of cement, 1 part of sand, and 2 parts of stone, and mixed quite dry.

No. 2 shall be made of the same mixture as No. 1, and mixed with sufficient water to make the concrete plastic.

No. 3 shall be the same as No. 1, but mixed very wet.

No. 4 shall approximate 1 part of cement, 2 parts of sand, 4 parts of stone, but shall be proportioned so that, after a mechanical analysis of the materials, the excess of cement over the voids of the sand shall be 10%, and the excess of mortar over the voids of the stone shall also be 10 per cent. It shall be mixed quite dry.

No. 5, same proportions as No. 4, but mixed plastic.

No. 6, same proportions as No. 4, but mixed very wet.

No. 7, 1 part of cement, 3 parts of sand, and 6 parts of stone. Mixed quite dry.

No. 8, same as No. 7, but mixed plastic.

No. 9, same as No. 7, but mixed wet.

No. 10 shall consist of a Portland cement which is free from iron. One specimen shall be mixed, of the proportions 1 : 1 : 2, quite wet.

No. 11 same cement as No. 10, 1 : 3 : 6, wet.

No. 12 commercial Portland cement high in alumina, mixed 1 : 1 : 2, wet.

No. 13 same cement as No. 12, 1 : 3 : 6, wet.

No. 14 of a commercial Portland cement low in alumina, 1 : 1 : 2, wet.

No. 15 same cement as No. 14, 1 : 3 : 6, wet.

No. 16 of an iron ore cement practically free from alumina, 1 : 1 : 2, wet.

No. 17 same cement as No. 16, 1 : 3 : 6, wet.

No. 18 of slag cement, 1 : 1 : 2, wet.

No. 19 same cement as No. 18, 1 : 3 : 6, wet.

No. 20 shall consist of the same materials and proportions as given for No. 7, but shall be most thoroughly well mixed (much better than commercial mixing), at the same time being quite wet.

No. 21 shall be the same as No. 7, but mixed with sea water, quite wet.

No. 22 shall be mixed of $\frac{9}{10}$ by weight of one part of standard Portland cement as No. 7, $\frac{1}{10}$ part by weight of hydrated lime, 3 parts of sand, 6 parts of stone, mixed wet.

No. 23 shall be of the materials given for No. 7 but in addition shall contain Sylvester mortar hereinafter described, mixed wet.

No. 24 shall be of the materials in No. 7 and in addition shall contain 5% by weight of the cement of finely pulverized clay, mixed wet.

In addition. there shall be fifteen cubes, 8 in. on each side, of 1 part of standard Portland cement, 1 part of sand, and 2 parts stone; and fifteen others of the same cement, mixed 1:3:6. One-third of these, after being thoroughly set, shall be permanently immersed in water; another third shall be supported at about half tide; and the rest shall be kept permanently dry but exposed to the weather.

There shall also be made briquettes, of the same cements and proportions of mortar as above described for concrete, of such number that they can be tested at intervals covering a period of years, some of which shall be kept in the laboratory, some exposed to the same conditions that the cubes will have; and enough briquettes shall be made of standard sand to compare the relative strength between standard and the materials actually used.

Testing of Materials.—All cement shall be thoroughly tested for all physical properties, and shall be subjected to chemical analysis. The sand shall be subjected to a thorough mechanical and physical analysis to ascertain the relative sizes of its grains and the quantity of foreign matter which it contains, if any. The same tests shall be applied to the stone. The various ingredients, such as sea water, hydrated lime, Sylvester mortar, and clay, shall be tested, in order that the exact nature of the material may be known.

Sand.—The sand shall be of a good quality, commercial bank sand, clean, coarse and sharp, as free from all impurities and foreign matter as can be obtained commercially. The stone shall be of trap rock which shall have passed a 2-in. ring and have been retained on a $\frac{1}{2}$-in. ring. It shall be as free from dust and dirt as commercially practicable.

Mixtures.—All materials shall be proportioned by volume, as given above for each specimen. A cubic foot of cement shall contain 100 lb. The sand and stone shall be measured on the basis that a barrel of cement contains 380 lb. net and measures 3.8 cu. ft. Samples of the sand and stone shall be weighed so that the proportion by weight (as well as by volume) will be known.

The quantity of water to be used shall be accurately measured for each batch, and shall be proportioned by experiment, so that the dry specimens shall just fail to show moisture when tamped in place; the

plastic specimens shall just barely begin to quake when tamped; and the wet specimens shall be proportioned so that the mortar will flow easily off the blade of a shovel and shall be wet enough to flow readily into place without being spaded or tamped.

The Sylvester mortar shall be mixed as follows, as given in Gillette's "Hand Book of Cost Data", pages 389 and following: A light-colored soft soap shall be dissolved in water, $1\frac{1}{4}$ lb. to 15 gal. of water, and 3 lb. of powdered alum shall be mixed with each bag of cement. After all the materials of the concrete are thoroughly mixed dry, water containing the soap in solution shall be used to mix the materials wet to the proper consistency.

Mixing.—All materials shall be thoroughly mixed in a batch concrete mixer of approved type. They shall be fed into the machine as quickly as possible, and shall remain for 2 min. after the last ingredient is added. For the specimen which is to be extra thoroughly well mixed, the material shall remain in the mixer for 12 min.

If the weather is cold, all frost shall be removed from the sand and stone by heating before the materials are placed in the mixer.

Placing.—The concrete, after mixing, shall be placed in the forms as quickly and continuously as possible, and, after proper tamping, shall not be again disturbed. In no case shall concrete which has been allowed to stand for more than $\frac{1}{2}$ hour be used, and in no case shall $\frac{1}{2}$ hour elapse between placing two batches of concrete in the same mould.

Forms.—The forms shall consist of planed and matched spruce lumber, so that they may be as tight as possible, and shall be braced so thoroughly as not to spring under the pressure of green concrete. The forms shall be left on for such a length of time that there shall be no damage to the concrete when they are removed. The Inspector shall be the judge as to when it is proper to remove the forms.

Reinforcement.—The columns shall be reinforced with an embedded steel bar, about $\frac{5}{8}$ in. square, which shall be bent into a U-shape and run throughout the length of the big specimens near two diagonally opposite corners, and the loop shall project a sufficient distance above the top of column to permit of its being easily hooked in case it is desired to remove it.

A hole, 3 in. in diameter, shall be cored in the upper 8 ft. of each specimen, to permit of examination from time to time to see if water has penetrated through the walls of the concrete to the hole.

Protection.—After the specimens are cast, they shall be protected from freezing, as far as possible, until they have set for a period of at least 5 days, and, after the forms have been removed, they shall be thoroughly and substantially braced, so that there shall be no danger of their tipping over.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

FINAL REPORT OF THE SPECIAL COMMITTEE TO INVESTIGATE THE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS

THE AMERICAN SOCIETY OF CIVIL ENGINEERS,
220 WEST 57TH STREET, N. Y. CITY.

GENTLEMEN: The Special Committee to Investigate the Conditions of Employment of, and Compensation of, Civil Engineers submitted its second report at the Annual Meeting held on January 20th, 1915. With that report there was presented statistical information based on 4 796 replies to circulars sent out by the Committee, the information being given in diagrammatic form and covering the following:

1.—Maximum, minimum, and average yearly compensation, together with that of the middle man or the man occupying a position where equal numbers of individuals receive a greater and a less annual compensation. These figures were given for every year of experience from 1 to 63 years, although the number of replies received from those who have been in active practice for more than 47 years were so few that the information with respect to them was considered of little value.

2.—The average yearly compensation according to the nature of employment, classified in eight groups, namely, States and Counties, National Governments, Municipalities, Technical Schools, Railroads, Private Companies, Consulting Engineers, and Contractors.

3.—A geographical classification arranged in six groups, namely, Southern States, Western States, New England States, Central States, Middle Atlantic States, and Foreign Countries.

4.—A classification separating graduates of technical schools from non-graduates, this being supplemented by a statement giving the relative ages of graduates and non-graduates for those whose experience covered from 2 to 15 years.

The report of the Committee was received and the Committee was continued. The Committee has endeavored to secure information concerning a larger number of engineers, and, with this in view, has extended its inquiries outside the membership of the Society. While

additional requests for information were sent out and many replies were received, the Committee was unable to present a formal report at the Annual Meeting of 1916, and simply reported progress.

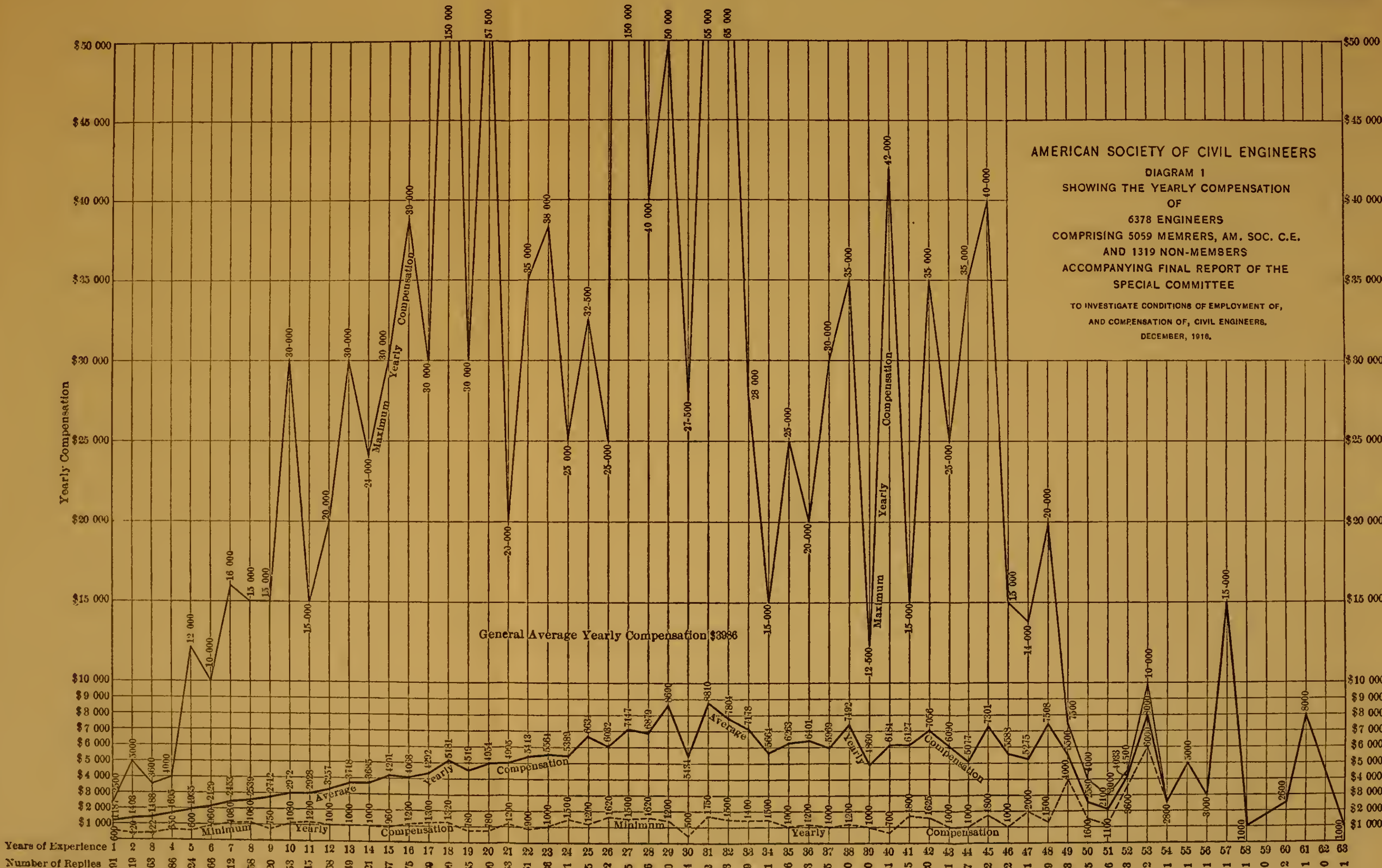
In accordance with the expressed wish of the Board of Direction, that the work of Special Committees be completed as soon as possible, the Committee now presents its final report.

During the summer of 1915 the Committee addressed the same questions which were addressed to those whose replies formed the basis of its last report to those who had become members of the Society since the last preceding circular was sent out, the number of inquiries so sent being 599, from which 263 replies were received. Inquiries were also addressed to 6 393 non-members of the Society, whose names were secured from the membership lists of fifteen local engineering organizations in different parts of the country, after having first eliminated from these lists all who were members of this Society. From these non-members 1 319 usable replies were received, which, together with the additional members of the Society heard from, brings the total number of returns received by the Committee to 6 378.

The Committee has considered the advisability of addressing letters of inquiry to members of the other National Engineering Societies, but has concluded that this would be inexpedient, for the reason that there are quite a number of members of these societies who are also members of the American Society of Civil Engineers, and they are probably those whose compensation or income from professional work is above the average, so that, if those who are members of this Society were excluded, the result would not indicate the average compensation of members of the other societies, and might be misleading. The Committee also made an effort to secure information from the different engineering schools, but it was found that, with two exceptions, the statistics collected by these institutions concerning their graduates, with respect to the matters which have been the subject of the Committee's investigations, were so incomplete that this idea had to be abandoned. An attempt was made to secure pertinent data from officers of railway and other corporations, municipalities, States, and Federal departments which employ large numbers of engineers, but they appeared to consider it impracticable to undertake the collection of such data for the Committee, and, without their active co-operation, it has not been possible to secure any information of value.

The Committee, therefore, is obliged to base its third report on the information received from the 6 378 engineers who have replied; and that these figures are worthy of serious consideration is obvious from the fact that the 5 059 members of the Society represent a gross annual professional income of not less than \$20 952 952, while the 1 319 non-members represent a gross annual income of \$4 467 709, or a total for those whose replies form the basis of our report of \$25 420 661.

PLATE XIV.
PAPERS, AM. SOC. C. E.
DECEMBER, 1916.
FINAL REPORT OF
SPECIAL COMMITTEE TO INVESTIGATE
THE CONDITIONS OF EMPLOYMENT OF, AND
COMPENSATION OF, CIVIL ENGINEERS.



The returns from the 263 additional members of the Society, the great majority of whom were younger men, when combined with those covered by the last report, result, as might have been expected, in lowering the average compensation from $4 224 to $4 142, or $82. The average annual compensation of the 1 319 non-members is $3 387, or $755 less than for the members of the Society, including the latest returns. The Committee realizes that in directing its inquiries to individuals outside of the membership of the Society, but members of local engineering organizations, it has addressed a number of men who are not really practising engineers, as the local engineering organizations almost always include in their membership men who may be simply interested in engineering and some who have done little, if any, professional work, and they have been frank enough to say so in their returns, and their replies are not included in our statistics.

Twenty-two of the replies indicated that the men who made them are employed as sales engineers or in other lines of commercial work, although they are graduates of engineering schools. These men appear to have turned their attention to this kind of work immediately after graduation. The Committee has not included these returns in its compilation, but they are so significant as to be deemed worthy of comment. They include men whose active work covers periods of from 1 to 22 years, although in all but four instances their experience in work of this character has been 10 years or less. A comparison of their earning power with that of men engaged in what is generally considered to be strictly engineering work indicates that it agrees very closely with the averages shown by the diagrams, even though the responsibilities which must be assumed are less than those of the practising engineer.

The Committee submits herewith five diagrams as follows:

1.—A diagram similar to that reproduced as Plate XL* in the last report, showing maximum and minimum average annual compensation for professional work of 6 378 engineers, including 1 319 who are not members of the Society.

2.—A diagram showing the average yearly compensation of 6 358 engineers, divided into members of the Society and non-members, together with the combined average.

3.—A diagram showing the average compensation of graduates and non-graduates, arranged according to 5-year periods.

4.—A diagram showing the average compensation of engineers grouped according to nature of service.

5.—A diagram showing the average compensation of engineers arranged in six geographical groups.

The first of the above diagrams includes all the returns which have been received. The second and third include all returns covering

* *Proceedings*, Am. Soc. C. E., for December, 1914.

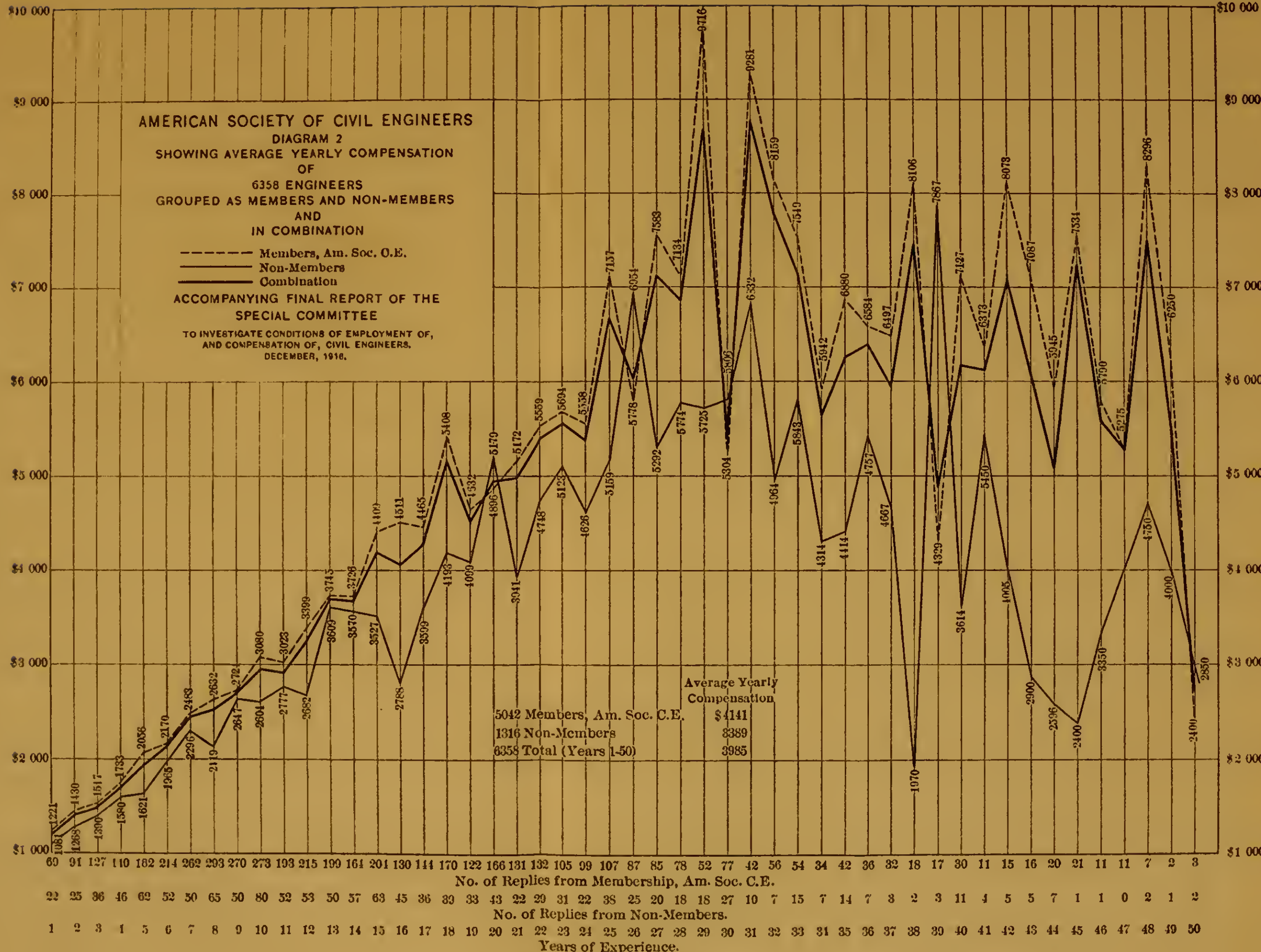
professional activity of 50 years or less, while the other two cover all those which are capable of being classified with certainty and which include 40 years or less of professional work.

Your Committee has considered the question as to whether exceptionally large professional incomes, say those above $25 000 a year, might not be due to some fortuitous circumstance or condition entirely apart from professional ability, and whether they should not be excluded from consideration in the preparation of the diagrams by arbitrarily reducing them to $25 000. This was tried and, while the effect was to modify very materially the curve showing maximum professional incomes, its effect on the curve of average compensation was very slight. The Committee believes that the data collected include practically all the very large professional incomes, and that an increase in the number of returns would tend to eliminate the irregularities of the curve. The Committee's conclusion has been that the returns should be shown as they were received.

A comparison of the diagrams with those presented with the last report will show that the broader scope of the Committee's inquiry has not produced any substantial changes in the results heretofore submitted. The line indicating the average compensation of non-graduate engineers falls below that showing the compensation of graduates, except during the first part of the first 5-year period, where the professional earnings of non-graduates appear to be slightly greater than those of graduates. The Committee has communicated with bodies which are collecting data concerning professional education, in the hope that it might secure information relative to the compensation of men engaged in other kinds of professional work. Its inquiries have not produced any definite results, and, so far as the Committee can learn, no data as complete as are herewith presented have been secured with respect to them. From such meager information as was obtainable, the Committee is convinced that the compensation for engineering work compares favorably with that received by men of any other profession. Engineers, like other professional or business men, are frequently desirous of being connected with important undertakings which will give them valuable experience and a certain prestige, and, in order to gain these, they are willing to accept salaries which are very small in comparison with the value of the services rendered.

The underpaid engineer does not always owe his failure to receive a salary commensurate with the importance or difficulty of his work to the ignorance or lack of appreciation of laymen, but it not infrequently is the fault of his engineering superior in the organization of which he is a part. The replies received by the Committee indicate that engineers in private practice sometimes employ men of extensive experience, and presumably of good ability, at salaries which young graduates with little or no experience are able to command, but which

PLATE XV.
PAPERS, AM. SOC. C. E.
DECEMBER, 1916.
FINAL REPORT OF
SPECIAL COMMITTEE TO INVESTIGATE
THE CONDITIONS OF EMPLOYMENT OF, AND
COMPENSATION OF, CIVIL ENGINEERS.



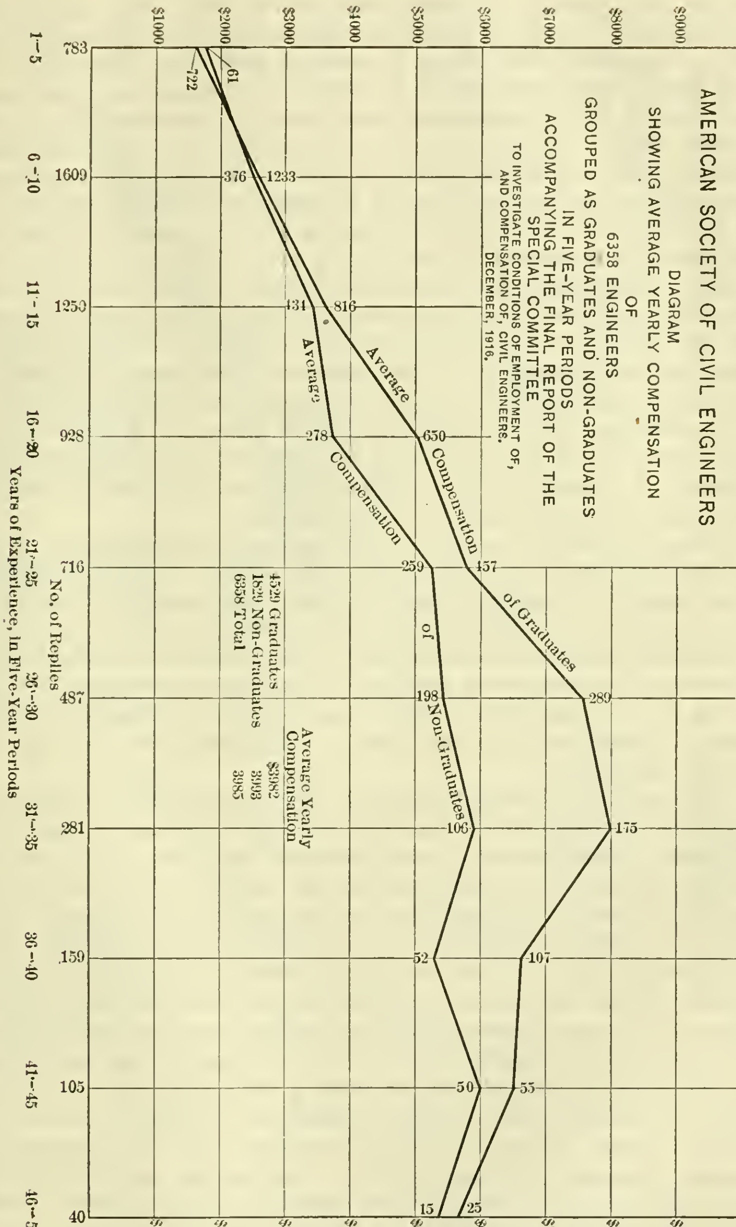

AMERICAN SOCIETY OF CIVIL ENGINEERS
DIAGRAM
SHOWING AVERAGE YEARLY COMPENSATION
OF
6358 ENGINEERS
GROUPED AS GRADUATES AND NON-GRADUATES
IN FIVE-YEAR PERIODS
ACCOMPANYING THE FINAL REPORT OF THE
SPECIAL COMMITTEE
TO INVESTIGATE CONDITIONS OF EMPLOYMENT OF, AND COMPENSATION OF, CIVIL ENGINEERS.
DECEMBER, 1916.
Average Compensation of Graduates
Average Compensation of Non-Graduates
Average Yearly Compensation
4529 Graduates $3982
1829 Non-Graduates 3993
6358 Total 3985
$1000 $2000 $3000 $4000 $5000 $6000 $7000 $8000 $9000
No. of Replies
783 1609 1250 928 716 487 281 159 105 40
1–5 6–10 11–15 16–20 21–25 26–30 31–35 36–40 41–45 46–50
Years of Experience, in Five-Year Periods

DIAGRAM 3.

are less than those of an ordinary mechanic who has a labor organization behind him. It may be urged that the competition for work on the part of engineers who employ a technical staff is so keen that it is necessary to take advantage of the needs of those seeking employment in order to secure professional work which is frequently let to the lowest bidder. Engineers in private practice are often criticized because they have not established a scale of charges on a percentage basis as have the architects, but in the offices of leading architects will be found young men who are willing to work for almost nothing for the sake of the experience they hope to gain. The fact remains that employing engineers are sometimes disposed to pay their men less than their services are actually worth. The Code of Ethics, adopted by the Society by letter-ballot on September 2d, 1914, lays special emphasis upon the relation of the engineer to his client and to that of competing engineers, who may be striving to secure the same contract or commission, toward each other, but it makes no mention of the obligations of the engineer as an employer to men of his own profession. It appears to lose sight of the need of guarding against underpaying as well as against underbidding.

The engineer, in some branches, unlike other professional men, is frequently unable to locate in one place until he can become known, even though his reputation may be local. He must go where work is in progress, and, when the particular work on which he has been engaged shall have been completed, he must move on to another place. Periods of unemployment are fatal to steady advancement, while a reasonable prospect of promotion, however slow, is likely to prompt men to accept less than the average compensation for the kind of service rendered.

In reading the observations made by those who have commented upon the compensation of engineers and the conditions of their employment, it has appeared to your Committee that many of those which appear cynical or pessimistic have been made by men who would probably have been failures in any occupation or profession, men who do not possess adaptability or even a fair degree of industry, and who attribute their failure to their unfortunate selection of a profession. These comments should not be given much weight. Perhaps there are too many engineers, but the eagerness of young men to adopt this profession is doubtless due to the indisputable fact that young graduates of engineering schools reach a self-sustaining basis, where they are at least able to support themselves, more quickly than do those of other professions. Much has been said lately about the general decrease in the registration at engineering schools, and this has apparently been viewed with alarm by their faculties. Your Committee does not consider it a bad omen for the profession. There is a need of better trained engineers rather than of more engineers, a need more particularly of men who are better grounded in the funda-

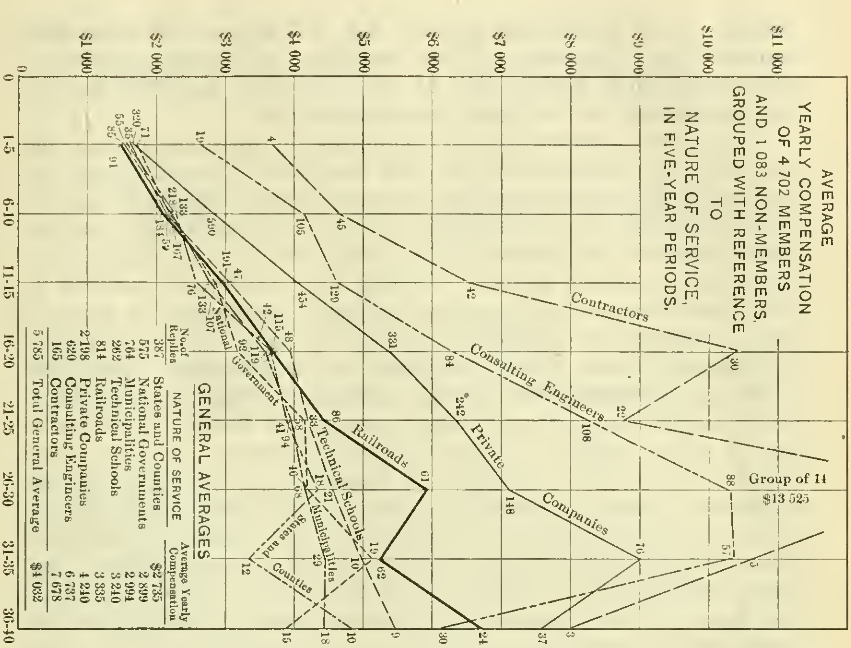


DIAGRAM 4.

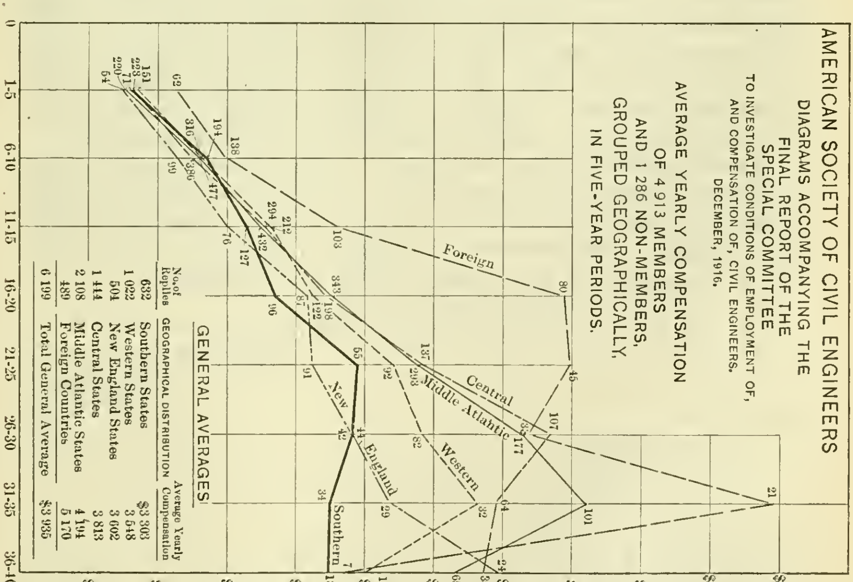


DIAGRAM 5.

mentals of the engineering sciences and who have at the same time acquired some knowledge of the economic or business aspects of engineering work, rather than of men who may have the greatest earning capacity on the day of their graduation.

The subject assigned to this Committee for investigation includes not only the compensation, but "the conditions of employment" of engineers. The information collected and herewith presented may be thought to relate only to compensation and not to conditions of employment, except to the extent that the latter may be the cause of, or may result from, the former. Judging from the replies received by the Committee and the extended comments accompanying some of them, conditions of employment are believed to be capable of expression chiefly, if not wholly, in terms of compensation. The Committee has repeatedly discussed the meaning of "conditions of employment" and what was the probable intent of the Society in the inclusion of these words in the title of the Committee. To give it the broadest interpretation to which it is susceptible and to follow the lead indicated by such interpretation would have led the Committee into a more or less controversial discussion of social conditions, and might have resulted in a report of greater length, but of no more value. That there lately has been a more general appreciation of the importance and dignity of the Engineering Profession cannot be denied, and the part which engineers are now taking, on the invitation of the Federal Government, in the investigation of the resources of this country and their prompt and effective utilization for national defense or in any other crisis, together with the more cordial co-operation between men in different branches of the Engineering Profession, will do much to increase further this estimate of the value of engineering service.

The Committee wishes to express its grateful appreciation of the co-operation which it has received from members of the Society and others, and for the valuable advice and assistance extended to it by the Secretary of the Society and members of his staff. It asks that this be accepted as its final report, and that it be discharged.

Respectfully submitted,

NELSON P. LEWIS,
Chairman.

COMMITTEE:
JOHN A. BENSEL,
S. L. F. DEYO,
DUGALD C. JACKSON,
WILLIAM V. JUDSON,
NELSON P. LEWIS,
C. F. LOWETH,
GEORGE W. TILLSON.

NOVEMBER 15TH, 1916.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROGRESS REPORT OF THE SPECIAL COMMITTEE ON MATERIALS FOR ROAD CONSTRUCTION AND ON STANDARDS FOR THEIR TEST AND USE*

To the American Society of Civil Engineers,

Gentlemen:

Your Special Committee on "Materials for Road Construction, and on Standards for Their Test and Use" respectfully submits the following Progress Report:

In accordance with opinions expressed at the Annual Meeting of 1916, the Committee has endeavored to incorporate in its 1917 Report the fundamental principles on which specifications covering each of the several types of roads and pavements should be based. The adoption of this plan has required a large amount of work on the part of each of seven Sub-Committees and eight meetings of the general Committee. The Committee presents these principles for the consideration of the Society and others interested, and hopes that advantage will be taken of the special Road Meetings, authorized by the Board of Direction, to be held on January 19th, 1917, for a full oral and written discussion of the report.

During the coming year the Committee intends to prepare a final report based on its 1915, 1916, and 1917 Reports and the discussions of these reports which have been presented at the Special Road Meetings held in connection with the Annual Meetings during the past three years.

General Principles Concerning Materials and Their Use, to be Observed in Framing Specifications for Pavements and Road Crusts.

Your Committee feels that while some of the following principles affecting the use of highway materials may seem to those trained or

* To be presented to the Annual Meeting, January 17th, 1917.

experienced in highway work of common knowledge and unnecessary of again being recorded, their expression here is advisable not only because of their general application to all surfacings, but because also a neglect of their proper consideration is often to be found among those annually attempting highway work. In some cases of pavements where the materials or methods of construction are peculiar, this fact has seemed to result in a neglect of these fundamental considerations. Your Committee recommends that neglect of these considerations be not allowed by any one to occur in any case.

Lines and Grades.—Where the lines of the highway are such as to invite high speed, or at least not to discourage high speed, consideration of the effects of speed of the traffic on the surfacing material must be had, and it is entirely possible that a choice of the material or the methods of using any particular material may be determined by the speed to be expected for the traffic, and thus be related to or connected with the lines itself of the highway.

A choice of the material, or methods of using a particular material, may be affected by the grades as fixed. Certain materials, or results of using materials, for highway surfacings will be unsatisfactory outside of certain limits of grades. Conservative practice has fixed the maximum limits for satisfactory results with grades, as follows:

Kind of Roadway.	Maximum Grade.
Gravel	12.0%
Broken stone	12.0%
Bituminous surface	6.0%
Bituminous macadam	8.0%
Bituminous concrete	8.0%
Sheet-asphalt	5.0%
Cement-concrete	8.0%
Brick (cement grout filler)	6.0%
Brick (bituminous filler)	12.0%
Stone block (cement grout filler)	9.0%
Stone block (bituminous filler)	15.0%
Wood block	4.0%

Width.—The width of the roadway to be built will be determined largely by local circumstances, but in view of the recent, constant, and rapid increase of traffic on highways, both in number of vehicles and in size of loads, it will be in the interest of economy for designs of highways to be made with proper consideration of further increase.

Where motor traffic forms a considerable proportion of the total traffic likely to use a highway, the unit width of traffic lines to be considered is 9 or 10 ft., instead of 7 or 8 ft. as heretofore, because of the greater clearance required for the safe passing of the units of such traffic.

Where bituminous pavements are laid, the edges need protection and a sudden transition from the pavement to any softer shoulder material should be avoided by means of extra width, or of cement-concrete or other edges, and such reinforcement of the shoulder material as may be necessary.

The width of roadways of rigid material, such as cement-concrete or vitrified block, should be at least equal to what would be prescribed under local conditions for a less rigid surfacing. The great difference between the firmness of a rigid roadway surfacing and of material frequently available for the shoulders thereto, often makes it necessary, for safety and convenience of traffic, as well as for economy of maintenance, that the rigid surfacing should be built wider than would answer for a more flexible surfacing, such as water-bound macadam, for instance, under the same local conditions.

Too narrow a width of roadway encourages, if it does not compel, concentration of traffic to such an extent as to make frequently unfair demands on what would otherwise be a suitable and efficient material for the surfacing. This may be especially noticeable at abrupt changes in the lines of the highway, where any tendency toward the improper concentration of traffic into too narrow areas should be avoided, as far as possible, by such adjustment or separation of lines, and adjustment of width, of crown, or of slope of the roadway surfacing, as will keep the strains of the surfacing material within reasonable limits for it.

Thickness.—The thickness of the pavement or surfacing, of course, will be dependent largely on its type, but it will also be affected by the presence or absence in the construction of an artificial foundation, and, in fact, on the character and ability of the base on which the surfacing is to rest. Approved practice establishes the limits given in Table 1 for the extremes of thickness for the various layers of the pavement or road crust.

TABLE 1.

Kind of roadway.	Thickness of artificial foundation,* in inches.	Thickness of sand cushion or binder course, in inches.	Thickness of wearing course, in inches.
Gravel	4 to 8	....	2 to 4
Broken stone	3 to 8	....	2 to 3
Bituminous surface	4 to 8	....	¼ to ½
Bituminous macadam	3 to 8	....	2 to 3
Bituminous concrete	3 to 8	....	1½ to 3
Sheet-asphalt	5 to 8	1 to 1½	1½ to 2
Cement concrete (One-course)	....	....	5 to 8
Cement concrete (Two-course)	4 to 8	....	2
Brick	4 to 8	¾ to 1½	3 to 4
Stone block	5 to 12	1 to 2	2½ to 5
Wood block	5 to 8	½	3½ to 4

* Not including extraordinary provisions such as V-drains or sub-base courses.

Although the general practice has been too often perhaps to use mass, for the sake of safety, in the preparation of the pavement, it now appears to be evident that some waste has been incurred in the past in this direction, and that a more scientific determination of the thickness, as well as of many other features of highway work, is possible, without sacrifice of safety and yet with economy. However, in view of the recent, constant, and rapid increase of the weight of, and consequently of the strains caused by, the traffic, it will be in the interests of economy for designs of highways to be made with proper consideration of further increases.

Drainage.—The use of any form of pavement or road crust, whether bituminous or non-bituminous, does not relieve the necessity of proper drainage in every case. It is not only necessary to provide for such under-drainage as will place and keep the sub-grade in a condition satisfactorily free from moisture and in a state of suitable efficiency, but it is also necessary to provide and to preserve economically such provisions for surface drainage as will, with the provisions for under-drainage, insure these results fairly permanently. Storm-water coming to the roadway must be carried quickly and rapidly away from it by automatic arrangements to the natural watercourses where it can be disposed of finally. The arrangements referred to and so made, such as inlets, ditches, gutters, and culverts, should be designed and placed so as to give the least possible offense to the users of the roadway and the abuttors, and yet be built so as to preserve their integrity and efficiency with the least need for attention and expense under even the most persistently adverse natural conditions. A proper longitudinal grade for ditches and gutters is particularly important, in order that the ill and wide effects of standing water may be avoided. A proper cross-section for ditches is also important, in order that the waterway may not become obstructed by the sliding in of the sides.

As related to drainage, the matter of the crown of the roadway is particularly important. The ideal roadway surface would be flat in cross-section were it not for the necessity of the automatic removal of surface water to the channels where it must be most conveniently carried along. Crowning the roadway tends to concentrate the traffic on the ridge where it is then most comfortable for the travelers, and the amount of crown which will result in this concentration on the ridge varies with the type of pavements. Also, the rate of crown necessary for the proper removal of storm-water to the gutters or ditches varies with the type, and with the provisions to be made for the cleaning and the upkeep of the roadway surface. In the general practice, the amount of crown for the shoulders of an uncurbed roadway has usually been a cross-slope of 1 in. per ft., the shoulders being of the natural earthy material, and this rate is to be recommended for shoulders, except in special cases.

The crown generally used in the construction of broken stone roadways is excessive when bituminous materials are used, and a crown of even ½ in. per ft. should be avoided when a lesser crown can be secured without detriment to the surface drainage.

For the various roadway surfacings, the practice generally observed and to be recommended is as given in Table 2.

TABLE 2.

Kind of roadway.	Crown Recommended: Maximum.	Minimum.
Gravel	1 in. to the ft.	½ in. to the ft.
Broken stone	¾ " " " "	½ " " " "
Bituminous surface	½ " " " "	¼ " " " "
Bituminous macadam	½ " " " "	¼ " " " "
Bituminous concrete	½ " " " "	¼ " " " "
Sheet-asphalt	¼ " " " "	⅛ " " " "
Cement-concrete	⅜ " " " "	¼ " " " "
Brick	⅜ " " " "	⅛ " " " "
Stone block	½ " " " "	¼ " " " "
Wood block	¼ " " " "	⅛ " " " "

Concave pavements of cement-concrete, vitrified block, or stone block may frequently be found advantageous for alleys, and, in such cases, the same rates of slopes in cross-section as those previously given should govern.

Artificial Foundations.—Where the character of the traffic justifies the use of an artificial surfacing, it also demands a correspondingly strong foundation. Whether or not an artificial foundation shall be supplied will depend on the local conditions, but in the selection of the materials and the methods of construction of the artificial foundation, every consideration should first be given to the possibilities for securing the greatest efficiency from the natural foundation. Economy in reference to the roadway will be had from the proper choice of the various materials available for artificial foundations, such as sand, gravel, broken stone, and concrete.

In the construction of a concrete foundation, the sub-grade should first be properly prepared and its greatest efficiency developed. The thickness of the cement-concrete artificial foundation usually laid is 5 or 6 in., but it may be varied advantageously according to the local conditions between 4 and 12 in. The thickness may be varied sometimes between the center of the roadway and the sides.

The most usual proportions for a cement-concrete foundation have been one part cement, three parts fine aggregate, and six parts coarse aggregate. This standard, however, is empirical rather than scientific, and a more rational proportion in any case should be developed according to the needs and facilities of each case. It may often be

desirable to increase the mass in some cases at the expense of unit strength, or to increase the mass for the sake of economy in the more expensive material. In mixing, placing, and completing a cement-concrete foundation, the principles expressed under the head, "Cement-Concrete Pavements", apply, and reference thereto should be had.

Sub-Grade.—The use of any form of pavement or road crust does not relieve the necessity for the construction of a well-drained, thoroughly compacted, homogeneous, and stable sub-grade in every case. Indeed, such improvement of the highway generally attracts heavier traffic and thus increases the stresses on the sub-grade. Even when an artificial foundation is to be constructed on the sub-grade, proper attention should be given to the preparation of the latter, in order that the greatest economy may be had in the design and expense for the artificial foundation, and, generally speaking at least, the higher the type and the more expensive the artificial foundation, the greater care should be exercised to develop to the utmost the possibilities of the sub-grade. Uniformity in its composition and compaction, as well as evenness of its surface, is far more important than has apparently been generally considered necessary up to this time, and permanence of all the desirable qualities in the sub-grade is equally important.

Materials.—Having determined the characteristics desirable for the materials to be used in any highway work, their description in the specifications should be concise, clear, and precise. Although, in some cases, it may not be possible to specify exactly the characteristics desired, it will be possible to specify that these qualities shall lie between certain exact limits, thus giving a reasonable tolerance to the determination of the quality by test, as well as avoiding uncertainty as to whether or not, in this respect, a quality of a material offered is suitable. The description of a material by using a trade name is permissible only in most unusual cases, and such a description as "equally good to" another similar material should never be used. Qualities of a material or methods of its use should not be left "to the satisfaction of the engineer" or "as determined by, or in, the opinion of the engineer".

Specific tests and such description of the methods of performing each test as will leave no room for doubt as to whether the results of the tests come within the limits of tolerance, should always be expressed either in detail, or by reference to the standards of some reputable authorities. The Committee recommends for this purpose the tests and methods of performing the same proposed by this Committee, to be found in detail in Appendix B.*

In this connection, the Committee wishes to call attention to its previously expressed conclusions, as follows:

* *Proceedings*, Am. Soc. C. E., for December, 1915, p. 2733.

The character of the stone to be used may influence the choice of a bituminous material.

Whatever method may be used in any case, it is as essential in bituminous work, as in water-bound construction, that a suitable quality of road metal be used.

By proper selection and use of a bituminous material, injury to property and deleterious effects on animal and vegetable life may be avoided, and also considerable hygienic advantage may result from the use of such materials on the highways.

Whenever comprehensive specifications are to be prepared, so as to admit a variety of types of bituminous materials, separate specifications, as may be necessary, should be prepared for each type.

Joints.—For the ordinary joints in block pavements, the materials and methods of filling should be selected so as to produce not only a surface which will retain to the utmost its imperviousness and the stability of the blocks themselves in place, but also as far as practicable, they should conduce toward evenness of wear of the surface of the pavement. If the blocks are resistant to abrasion, but perhaps inclined to round off at the edges of the upper surface under traffic, such filling of the joints is desirable as will lend additional resistance in the blocks to this rounding off at the joints.

Joint fillers are naturally divided into two main classes—the cement mortar filler and the bituminous filler. As it is desirable to secure a suitable water-proof wearing course for pavements, sand should never be used alone as the joint filler.

As regards the cement mortar joints, the proportions of cement, sand, and water will be affected by local conditions. Where the blocks are extremely resistant and the highest quality of results is desired, a 1: 1 mix of sand and cement is necessary. Where the blocks are of less resistant material and conditions demand economy, a 1: 1 mix of cement and sand may be found satisfactory. Great care is necessary in mixing and applying the mortar or grout. To insure uniformity, there should be a constant agitation of the mix up to the moment of its application, and no more water than is necessary for proper fluidity should be used. Success with joints of this kind is dependent in a large degree on the allowance of ample time for the grout to set thoroughly before the traffic is admitted to the roadway.

A bituminous filler may be preferred to a cement-grout filler, on account of the lower cost of street-opening repairs, the better foothold provided for horses, and the securing of a more resilient, and hence less noisy pavement. On steep grades, where some roughness of surface may be desirable for the sake of affording better foothold for animals, some openness at the top of the joint is desirable, and the bituminous joint fillers may be preferred. With bituminous joint fillers, care must be taken to select materials which will not be too

brittle in cold weather and so chip out from joints under traffic, and which will not be so soft in hot weather as to flow out of the joints between the blocks. It is believed, although not yet generally admitted as having been actually proven by experience, that the use of a bituminous mastic for joint filling would be an improvement over the customary practice of using bituminous material alone for this purpose. Great care should be taken with bituminous fillers of any kind to insure the actual filling of the joints between the blocks, and great care must be taken to insure this result.

Expansion-Contraction Joints.—Joints at intervals across certain types of pavements, such as brick and cement-concrete, as well as along the curbs, have been used to compensate for a more or less unavoidable movement of the pavement slab, which takes place under different conditions of moisture, or temperature of the air. In cases where expansion-contraction joints across the roadway at intervals are decided on for installment, the Committee recommends the use of bituminous material and the abandonment of all forms of the so-called "armored" joints, because of the smaller amount of interruption to the homogeneity of the roadway surface thus secured.

Shoulders and Gutters.—Where rigid or fairly rigid pavements are laid, their edges should be protected and the sudden transition from such a pavement to any softer shoulder material avoided by means of edges or such reinforcement of the shoulder material as may be necessary. The line or strip of contact between a cement-concrete roadway and the flanking material of the shoulders being the zone of weakness under traffic, it is important to accommodate the traffic and to protect the roadway as well as the shoulders from the formation of ruts along this line. This is especially true when the roadway is so narrow as to result in the frequent passage of vehicles from the pavement to the shoulders.

Such material for and construction of the shoulders should be had as will result in their being capable of efficient and economical maintenance under the local conditions existing or likely to prevail.

The shoulders may be reinforced with paving, concrete, macadam, gravel, or similar surfacings; or they may be of the natural local material available, due consideration being given to the advisability of tapering down from a relatively high rigidity of the roadway itself to any soft natural material at the outside edges of the road. The selection of materials and methods of construction for the shoulders should be made with careful consideration of the demands likely to be made by traffic, and by other factors in the problem, and should provide an elastic limit in the shoulders considerably higher than the stresses likely to come on them.

Gutters should be paved with such material and in such a manner as to preserve as permanently as possible their imperviousness under

their loads of water and the destructive effects of traffic coming on them. Their form should be such as will be least objectionable to traffic, considering the necessities for their peculiar purposes.

Finishing of Surface.—An objectionable slipperiness of many pavements may be decreased or prevented by proper precautions during construction or by proper treatment thereafter. The length of time that a finished pavement should be closed to traffic in order to season properly before use varies from a few hours to several days, dependent on the character of the material and methods used and on climatic and other local conditions. Pavements in which Portland cement is used for filling the joints or in the mass of the surfacing itself should seldom, if ever, be closed for less than two weeks after completion. Although the plans and specifications usually call for the surface to be finished to definite cross-sections, grades, or contours shown on the plans, questions frequently arise under contracts as to the importance of variations in the finished surface. The Committee has under consideration standards covering this detail.

Gravel Roads.

The subject of gravel roads embraces a great variety of styles of construction, from the simple expedient of surfacing the existing roadway with run-of-the-bank gravel from near-by pits to the construction of an improved highway with all the necessary drainage structures and improvements of grade attending a broken stone roadway.

The method of treating the gravel itself may vary from the application as it is found in the pit to the separation into sizes, and even to passing the gravel through the crusher before screening. In general, we may separate gravel roadways into two classes:

First, those in which the gravel is screened and applied in the same manner as with a broken stone roadway. This may be with or without crushing the gravel.

Second, those in which the gravel is applied to the roadway in its natural state as found in the pit, with or without the addition of other material, or the natural material may be passed through the crusher before application to the roadway.

The Committee believes that a more general use of gravel, especially in the surfacing of earth roads, should be encouraged. The low first cost and ease of maintenance should help materially to increase the mileage of serviceable roads in the country districts.

In the first case, with rounded gravel, the tendency toward dislodgment under traffic is greater than with angular broken stone, and hence, in order to reduce this tendency, the size of the pieces in the courses of the roadway must be somewhat smaller with gravel than in the case of broken stone.

In the second case, the selection of the material will be governed by the gravel available in the locality where the roadway is to be constructed. Every endeavor should be made to select a material that will show, by test, its fitness as regards hardness, toughness and cementing power. The gravel should show on mechanical analysis a grading of material which will contain sufficient stone of the larger size to insure stability and wearing qualities under traffic, and which will contain sufficient finer material to insure a proper bond. The best material will be composed of gravel graded so that it will have a maximum density.

Though the most available material will have a wide range as to sizes, the Committee believes that the following specification for sizes, adopted by the American Society of Municipal Improvements in 1916, may be followed safely:

"Two mixtures of gravel, sand and clay shall be used, hereinafter designated in these specifications as No. 1 product (for top course) and No. 2 product (for middle and bottom courses).

"No. 1 product shall consist of a mixture of gravel, sand and clay, with the proportions of the various sizes as follows: All to pass a 1½-in. screen and to have at least 60 and not more than 75 per cent. retained on a ¼-in. screen; at least 25 and not more than 75 per cent. of the total coarse aggregate (material over ¼ in. in size) to be retained on a ¾-in. screen; at least 65 and not more than 85 per cent. of the total fine aggregate (material under ¼ in. in size) to be retained on a 200-mesh sieve.

"No. 2 product shall consist of a mixture of gravel, sand and clay, with the proportions of the various sizes as follows: All to pass a 2½-in. screen and to have at least 60 and not more than 75 per cent. retained on a ¼-in. screen; at least 25 and not more than 75 per cent. of the total coarse aggregate to be retained on a 1-in. screen; at least 65 and not more than 85 per cent. of the total fine aggregate to be retained on a 200-mesh sieve."

The condition of a gravel roadway depends largely on a continuous and systematic maintenance. The Committee is of the opinion that this can be best accomplished by an intelligent use of the hone or road drag, and the addition of fresh material from time to time. Where it is advisable to use a surface coat of bituminous material, the Committee is of the opinion that it is better to use a bituminous material of such consistency that it can be applied at a temperature below 52° cent. (125° Fahr.), applying it uniformly under pressure of not less than 20 nor more than 75 lb. per sq. in., and in small quantities (not to exceed ¼ gal. per sq. yd.), than to attempt to apply and maintain a thick carpet with heavy bituminous material.

Bituminous material should be applied only after the surface shall have been thoroughly compacted by traffic.

With gravel such as quartz, the cementation of which is low, a highly cementitious void filler is desirable, and a moderate quantity of clay or loam may be permissible.

In drafting specifications, the refinement to be used in the methods of construction will depend on the kind and amount of traffic to be sustained, the character and quality of the gravel to be obtained in that particular locality, and other local conditions.

As a general conclusion, however, it may be said that addition of gravel to the road surface in all forms is generally an improvement, and refinement in the methods of construction of gravel roads should be carried to a point where further refinement would not be economical.

Broken Stone Roads.

General.—General principles as to lines, grades, widths, drainage, and foundations, as outlined elsewhere in this report, are applicable to this type of surface.

Artificial foundations of cement-concrete are not advisable or economical for this type of road. The most preferable foundations consist of broken stone (either field or ledge), gravel, clean, coarse sand, or cinders.

Thickness.—In determining the thickness of the crust, consideration must be had of the character of the foundation, and of the weight of vehicles to be supported. If laid on a strong stone foundation, a maximum thickness of 6 in. of broken stone is sufficient; if on a weaker foundation, the thickness should be increased. If the vehicles passing over the road are comparatively light, that is, of 1 or 2 tons on four wheels, the thickness obviously need not be as great as when 4-ton or heavier vehicles are to be supported.

Material.—All broken stone should be clean, rough-surfaced, sharp-angled, of compact texture, and uniform grain. It should preferably be of such quality that, using standard laboratory tests, it shall show a percentage of wear not greater than 5 (French coefficient of wear not less than 8), and a toughness of not less than 6.

The broken stone should be separated into component sizes by passing the product of the crusher over rotary screens having circular openings, the different sizes of stone being collected in separate bins. The separation of sizes is governed somewhat by the thickness at which the crust is to be laid. If a 6-in. surface is to be laid, the maximum size should not exceed that of stone passing a 3-in. screen, whereas if the pavement is to be 7 in. or more in thickness, a 3½-in. screen is permissible. In all cases the stone should be spread and rolled in two or more courses, the largest size being used in the lower course and the smaller sizes in the upper course or courses, each course being spread in such manner that there will be uniformity in its density.

Such uniformity is accomplished by spreading from piles dumped on boards or alongside the road, or by some automatic spreading wagons. Sizes properly used on a 6-in. road are as follows: Bottom course, stone passing over a 1½-in. screen and through a 2¾-in. screen, the stone being spread so that it shall have a thickness of 4 in.; top course, stone passing over a ⅝-in. screen and through a 1½-in. screen, this course being 2 in. thick.

On an 8-in. road, sizes properly used are as follows: Bottom or first course, 2¼ to 3½ in.; 3½ in. thick. Second course, 1¼ to 2¼ in.; 2½ in. thick. Third course, ⅝ to 1¼ in.; 2 in. thick.

The sizes of stone thus indicated represent the sizes of the screens, and the thickness indicates that after rolling.

The product passing through a ⅜, ½, or ⅝-in. screen should be used as a binder, and on two-course work should be applied on the top course only, whereas on three-course work, the second course should be lightly covered with this material.

Products of broken stone obtained from portable and stationary stone-crushing and screening plants, while complying with a given specification of the type now ordinarily used, vary to a considerable extent, due to variations in the plant and its operation, such as kind of rock, type and method of operation of crushing plants, methods of separation of products, differences in lengths and diameters of sections of rotary and shaker screens, and differences in inclination and rate of operation of screens.

The necessity for more carefully drawn specifications covering the sizes of the particles of which a given product of a stone-crushing and screening plant is composed, is illustrated by Table 3, a mechanical analyses of two products obtained from the same plant, both of which products passed over a section of a rotary screen having circular holes 1¼ in., and through a section of a rotary screen having circular holes 2¼ in., in diameter.

TABLE 3.

	Sample "A." Percentage.	Sample "B." Percentage.
Passing ¼-in. screen	0.3	0.2
" ½ " " and retained on ¼-in. screen	0.4	1.1
" ¾ " " " " " ½ " "	2.2	12.6
" 1 " " " " " ¾ " "	8.0	37.5
" 1¼ " " " " " 1 " "	29.1	40.9
" 1½ " " " " " 1¼ " "	27.1	7.7
" 2 " " " " " 1½ " "	32.9	0.0
	100.0	100.0

It is obvious that for many forms of construction, in order to secure successful results, greater care must be used in the writing of specifications for products of broken stone. The Committee recommends the general adoption, as soon as practicable, of the following "Proposed Standard Form of Specifications for Certain Commercial Grades of Broken Stone", as recommended by Committee D-4, of the American Society for Testing Materials, in its 1916 Report:

The broken stone shall consist of one product of the operation of a stone-crushing and screening plant, without recombining or mixing, and shall conform to the following mechanical analysis, using laboratory screens:

* Passing .... in. screen (having smallest holes selected) from .... to .... per cent.

* Passing .... in. screen (having next to largest holes selected) from .... to .... per cent.

* Passing .... in. screen (having largest holes selected) from .... to .... per cent.

Example.—The broken stone shall consist of one product of the operation of a stone-crushing and screening plant without recombining or mixing, and shall conform to the following mechanical analysis, using laboratory screens:

Passing ¼-in. screen		3 to 10%
" 1-in. "	and retained on ¼-in. screen	80 to 95%
" 1½-in. "	" " " 1-in. "	2 to 10%
Total passing 1½-in. screen		100%

In this form of specification an attempt is made to cover in the mechanical analysis only the limits of the smallest and largest particles. No attempt is made to secure a carefully graded aggregate, but simply a product suitable for the type of road or pavement in question.

Construction.—Each course of a broken stone road should be thoroughly rolled with a roller weighing from 10 to 15 tons, the rolling being done first along the sides and gradually approaching the center, and being continued until there is no movement of the stone ahead of the wheels of the roller.

The binder should be used on the top course in such quantity that, after alternate spreading of binder and watering, with continuous rolling, the voids become so filled as to result in a wave of grout being pushed along the surface by the front wheel of the roller.

* An engineer should base the selection of screens, to be used in the specification for a given product of broken stone, on the results of mechanical analyses of many similar products obtained from portable and stationary crushing and screening plants which supply the locality in which the specification is to be used.

After the completion and binding of the top course, a thin layer of screenings or stone dust should be applied to the surface in sufficient quantity to cover it evenly.

Broken Stone Roads with Bituminous Surfaces.

General.—All the principles, materials, and methods relating to broken stone roads apply also to such roads when covered with a bituminous surface, such surface being applied after the entire completion of the broken stone road.

Bituminous Material.—Either refined tar, cut-back asphalt, or asphaltic oil may be used for the bituminous surface. It has been demonstrated that bituminous material of such consistency that it can be applied at a temperature below 52° cent. (125° Fahr.) is preferable to heavier material, and that the application of a quantity in excess of ½ gal, per sq. yd. is inadvisable.

Construction.—The broken stone road on which a bituminous surface is to be applied should be thoroughly completed and allowed to dry. Traffic may advantageously be allowed over the road before the application of the bituminous material, provided it is not of such volume or nature as to injure the upper course. The application of a bituminous surface should be made on the exposed stone surface of the upper course, such exposed surface being obtained by thoroughly removing with brooms or sweepers the binding material or dust that may have been applied or accumulated thereon. The bituminous material should be applied by a pressure distributor designed so that the material shall be distributed uniformly and with a pressure of not less than 20 lb. per sq. in. Such pressure should not be greater than 75 lb. in order not to atomize the material.

After the bituminous material is applied it should be covered immediately with the toughest grit obtainable that will pass through a screen with openings not less than ⅜ in. nor greater than ⅝ in., just enough of such material being used to cover the bituminous material. It is advantageous, but not entirely necessary, to roll with a steam roller after the application of the grit.

Bituminous Macadam Pavements.

General.—The general principles applying to broken stone roads also apply to bituminous macadam pavements.

Materials.—The broken stone should be of a quality equal to that prescribed for broken stone roads, and should have the same characteristics. The bituminous materials may be of asphalt or refined tar.

Construction.—The principles relating to thickness applicable to a broken stone road are likewise applicable to bituminous macadam pavements, and thorough rolling, including the rolling of the upper course, both before and after the application of the bituminous material, is

also necessary. As it is desired to bind only the upper course with bituminous material, it is necessary, in order to prevent waste by penetration, that there should be no appreciable voids in the next lower course. It is not necessary, however, to flush the filler or binder in this course to the same extent as is necessary in binding the top course of a water-bound road, and it is absolutely essential that no binder should cover the stones of the lower course when the top course is spread.

The quantity of bituminous material used should be just sufficient to penetrate through the upper course and fill the voids; such penetration and filling is accomplished by the application of approximately 1 gal. of bituminous material to the square yard for each inch in thickness of the upper course.

The use of a pressure distributor in applying the bituminous material is essential, and the distributor should be of such type that absolutely uniform application may be accomplished, and that no ruts are formed in the surface by the wheels supporting the distributor.

The bituminous material should be applied at such a temperature that it will flow freely, and, to insure proper penetration, the stone should be dry and clean, and the air temperature should not be lower than 10° cent. (50° Fahr.) during application.

In order to secure a proper surface, the covering material should preferably consist of the crusher product passing over a $\frac{1}{4}$-in. screen and through a $\frac{3}{4}$-in. screen. Finer material, however, may be used for covering if a slippery surface is not objectionable, but the use of material passing through a 10-mesh sieve should be avoided.

Bituminous Concrete Pavements.

The principles to be covered in drafting specifications for bituminous concrete pavements will be classified under the three types into which these pavements generally may be divided. These types are designated as follows:

- (*A*) A bituminous concrete pavement having a mineral aggregate composed of one product of a crushing plant;
- (*B*) A bituminous concrete pavement having a mineral aggregate composed of a certain number of parts by weight or volume of one product of a crushing plant and a certain number of parts by weight or volume of fine mineral matter, such as sand or stone screenings;
- (*C*) A bituminous concrete pavement having a predetermined mechanically graded aggregate of broken stone or gravel, either alone or combined with fine mineral matter, such as sand or broken stone screenings.

Bituminous Concrete Pavements, Class *A*.

Mineral Aggregate.—Broken stone, because of the satisfactory bond secured, should be used wherever possible, although bituminous concretes constructed with gravel have proved satisfactory for light traffic where great care has been taken in the selection of the gravel and in the construction of the pavement.

Broken stone should be clean, rough surfaced, sharp angled, of compact texture, and uniform grain. If the pavement is to be subjected to medium or heavy traffic, the broken stone used for the construction of the wearing course should show a loss or abrasion of not more than 3.5% and its toughness should not be less than 13.

Especial care is required in drafting the specifications covering the broken stone or gravel to be used. An excess of large or small sized stone or gravel should be avoided. Practice has demonstrated that a mineral aggregate composed of those materials which will comply with the following mechanical analysis, using laboratory screens having circular openings, will produce satisfactory results: All the material shall pass a $1\frac{1}{4}$-in. screen; not more than 10% nor less than 1% shall be retained upon a 1-in. screen; not more than 10% nor less than 3% shall pass a $\frac{1}{4}$-in. screen.

Although satisfactory pavements have been constructed using unheated mineral aggregates and suitable bituminous cements, service tests demonstrate that the best results are secured by using for the mineral aggregate broken stone or gravel which is heated until thoroughly dry to between 66° cent. (150° Fahr.) and 121° cent. (250° Fahr.). If revolving dryers in which the flame is permitted to come in contact with the aggregate are used, great care should be taken to ensure uniformity of heating and to avoid the danger of burning the aggregate.

Bituminous Cements.—Experience has demonstrated that the most efficacious bituminous concrete pavements of Class *A* are constructed by using suitable asphalt cements or refined tars in the mix and asphalt cements for seal coats.

In order to obtain a fluidity of the bituminous material which should be sufficient to ensure a proper coating of the mineral particles in cases where a heated aggregate is used, and also to prevent injury to the bituminous material, the asphalt cements should be heated to a temperature between 135° cent. (275° Fahr.) and 177° cent. (350° Fahr.), and refined tars to a temperature between 93° cent. (200° Fahr.) and 135° cent. (275° Fahr.).

Mixing.—The quantity of bituminous cement to be used in the mix will depend on the kind of broken stone or gravel and bituminous cement, the character of the aggregate, the climatic conditions, etc. For the aggregate heretofore mentioned, the bituminous concrete mixture should contain between 5 and 8% by weight of bitumen.

The bituminous concrete should be mixed in mixers designed and operated so as to produce and discharge a thoroughly coated and uniform mixture of non-segregated aggregate and bituminous cement. Except on small contracts and for repair work, mixers which provide for the heating of the aggregate by the use of a flame in the mixing chamber should not be used, on account of the danger of burning the aggregate or the bituminous cement.

Laying.—To ensure ease of manipulation and the proper compaction of the bituminous concrete, the mixture as delivered on the roadway should have a temperature of not less than 66° cent. (150° Fahr.). Experience has demonstrated that a thickness, after rolling, of 2-in. of bituminous concrete is economical and efficacious. In order to secure an even surface and adequate compaction by a thorough interlocking of the particles of the aggregate, a tandem roller weighing between 10 and 12 tons should be used.

Seal Coat.—A seal coat should always be used on this type of bituminous concrete, as maintenance charges and annual cost will be reduced materially thereby. The seal coat should consist of from ½ to 1 gal. per sq. yd. of asphalt cement uniformly distributed, preferably by the use of a hand-drawn distributor followed by a squeegee. The bituminous cement should be covered with an application of stone chips which should be rolled.

Seasonal Limitations.—Bituminous concrete of this type should not be mixed or laid when the air temperature in the shade is lower than 10° cent. (50° Fahr.), as otherwise it is difficult, under average conditions, to secure an even and well compacted wearing course.

Bituminous Concrete Pavements, Class *B*.

Specifications for pavements of this class have generally stipulated that so many parts of broken stone or gravel and so many parts of sand or other fine material are to be mixed with a certain quantity of bituminous cement. By the use of this specification, unless under unusual supervision, it is not practicable to secure a well-graded aggregate. Although in many cases the mixture contains an excess of broken stone with insufficient fine material to fill the voids therein, in other cases it contains an excess of sand in which the broken stone is contained as isolated particles. In general, because of the conditions described, either bituminous concrete pavements of Class *A* or Class *C* should be used.

Bituminous Concrete Pavements, Class *C*.

This type includes the so-called "Topeka" mixture, asphalt block, and several kinds of patented pavements.

Topeka Bituminous Concrete Pavement.—If the Topeka pavement specification embodies the grading, as contained in the decree of 1910, namely,

"Bitumen, from 7 to 11 per cent.

Mineral aggregate, passing	200-mesh	screen, from	5 to 11 per cent.
" " "	40	" " "	18 " 30 " "
" " "	10	" " "	25 " 35 " "
" " "	4	" " "	8 " 22 " "
" " "	2	" "	less than 10 per cent.,"

special provisions should be made in the specifications covering the broken stone and sand to be used, in order to secure satisfactory grading. Otherwise, the principles stated under "Bituminous Concrete Pavements, Class *A*", should be followed, except that a seal coat is not considered necessary under many conditions where this type of pavement is used.

Asphalt Block Pavements.—Specifications for asphalt block pavement should cover thoroughly the several components of the bituminous concrete used, the manufacture of the blocks, the blocks *per se,* and the details of construction of the pavement.

Experience has demonstrated that the blocks should be composed of asphalt cement, crushed trap rock, and mineral dust. All particles of the trap rock should pass a ¼-in. screen, and the mineral dust or filler should consist of powdered limestone or Portland cement. The bitumen content of the blocks should be between 6.5 and 9.5%, depending on the grading of the mineral aggregate and the method of manufacture. The specifications should contain specific requirements with reference to the asphalt cement, filler, and the grading of the mineral aggregate, which latter should be similar to the following:

Passing 200-mesh sieve	20 to 35 per cent.
Passing 80-mesh sieve and retained on 200-mesh sieve	7 " 15 " "
Passing 20-mesh sieve and retained on 80-mesh sieve	12 " 30 " "
Passing ¼-in. screen and retained on 20-mesh sieve	30 " 50 " "
Retained on ¼-in. screen	0 " " .

The specifications should also cover the specific gravity of dry blocks, which should not be less than 2.45 at 25° cent. (77° Fahr.) and the percentage of absorption of water of the blocks, after being dried for 24 hours at a temperature of 65° cent. (149° Fahr.), should not be more than 1% after immersion in water for 7 days. The blocks should be about 5 in. in width and 12 in. in length, and 2, 2½, or 3 in. in depth, depending on traffic conditions.

The blocks should be laid on a fresh ½-in. mortar bed which covers a cement-concrete foundation. After being laid, the blocks should be covered with a thin layer of clean, dry, fine sand which shall be thoroughly swept into the joints until they are filled.

Patented Bituminous Concrete Pavements.—In cases where patented bituminous concrete pavements of Class *C* are used, the same fundamental principles observed under "Bituminous Concrete Pavements, Class *A*" should be followed, especially in the case of covering

in detail the composition and grading of the mineral aggregate, and the physical and chemical properties of the bituminous cements used.

Sheet-Asphalt Pavements.

A sheet-asphalt wearing course, consisting of predetermined graded sand, filler, and asphalt cement, should be laid to a compacted thickness of not less than 1½ in. and not more than 2 in., on a binder course of bituminous concrete consisting of broken stone or broken stone and sand mixed with asphalt cement, the binder course having a compacted thickness of not less than 1 in. nor more than 1½ in.

Materials.—For heavy or medium traffic, the so-called close binder should be used instead of the open binder, as the former possesses greater inherent stability than the latter. Specifications for the grading of open binder should be similar to those for the aggregate for Bituminous Concrete Pavements, Class *A*; and, for a close binder, similar to the following:

Ninety-five per cent. of the binder aggregate shall pass a screen having circular openings the diameter of which shall be of three-quarters the thickness of the binder course to be laid. The remaining 5% shall not exceed in their smallest dimension the thickness of the binder course to be laid. The binder aggregate shall be graded from coarse to fine so as to have the following mesh composition:

Passing 10-mesh sieve...........	15 to 35%	Total passing ½-in. screen, 35 to 85%.
Passing ½-in. screen and retained on 10-mesh sieve.............	20 to 50%	

The broken stone for the binder should be heated to a temperature between 107° cent. (225° Fahr.) and 177° cent. (350° Fahr.).

The sand for the wearing course shall be carefully graded. For pavements to be subjected to medium or heavy traffic, there should be a preponderance of the finer particles; and for pavements to be subjected to light traffic, there may be a preponderance of the coarser particles. Specifications for a sand for wearing courses to be subjected to medium or heavy traffic should be similar to the following: The sand shall be hard, clean, and moderately sharp. On sifting it shall have the following mesh composition:

Passing 200-mesh						0 to 5%	Total passing 80-mesh and retained on 200-mesh, 20 to 40%.
"	100-mesh and retained on 200-mesh					10 " 25%	
"	80	"	"	"	" 100 "	6 " 20%	
"	50	"	"	"	" 80 "	5 " 40%	
"	40	"	"	"	" 50 "	5 " 30%	
"	30	"	"	"	" 40 "	5 " 25%	Total passing 10-mesh and retained on 40-mesh, 12 to 45%.
"	20	"	"	"	" 30 "	5 " 15%	
"	10	"	"	"	" 20 "	2 " 15%	

The sand when mixed with the asphalt cement should have a temperature between 135° cent. (275° Fahr.) and 190° cent. (375° Fahr.).

The filler should be thoroughly dry limestone dust, or dust from other equally satisfactory stone, or Portland cement, the whole of which should pass a 30-mesh sieve and at least 66% of which should pass a 200-mesh sieve. The surface mixture should contain from 6 to 20% of this filler, depending on the kind of sand and asphalt used and the traffic conditions on the street or streets to be paved.

The specifications should contain detailed requirements covering the physical properties of the asphalt cement, and should prescribe the bitumen content of the binder course and sheet-asphalt wearing course mixture. For the grading mentioned, the bitumen should be, for the close binder, from 4 to 7%; and for the sheet-asphalt wearing course mixture, from 9.5 to 13.5 per cent. The asphalt cement when used should have a temperature between 121° cent. (250° Fahr.) and 177° cent. (350° Fahr.).

Construction.—The asphalt cement and broken stone, or broken stone and sand for the binder course, and the asphalt cement, sand, and filler for the wearing course, should be thoroughly mixed by machinery until a homogeneous mixture is produced in which all the particles are thoroughly coated with asphalt cement.

When brought to the work, the temperature of the binder mixture should be between 93° cent. (200° Fahr.) and 163° cent. (325° Fahr.), and of the wearing course mixture between 110° cent. (230° Fahr.) and 177° cent. (350° Fahr.). The binder course and the wearing surface should be compacted separately by rolling with a self-propelled roller weighing not less than 200 lb. per inch of width of tread, the rolling being carried on continuously at the rate of not more than 200 sq. yd. per hour per roller until a satisfactory compression is obtained. Excessive use of water on the steam roller while compacting the courses of the pavement should not be permitted. During the rolling of the wearing course, a small quantity of Portland cement should be swept over its surface. In cases where sheet-asphalt is constructed next to the curb, it is advisable to coat the surface for a space of 12 in. next to the curb with hot asphalt cement.

Cement-Concrete Pavements.

General.—A thickness of from 5 to 8 in., as stated in the general principles, may ordinarily be considered sufficient for a concrete slab, and if it seems advisable, from motives of economy, the thickness may be diminished from the center of the slab to the edges. Special conditions may call for variations, even outside of the limits given. The character and drainage of the sub-grade, its probable stability as a foundation, as well as the nature and amount of traffic, are

some of the factors which enter into the rational determination of the thickness of the slab.

Materials.—The cement should be tested by the methods devised and recommended by the Special Committee of the American Society of Civil Engineers on Concrete and Reinforced Concrete,* and should meet the requirements adopted by the American Society for Testing Materials, as printed in the 1915 Year Book of that Society.

The Committee wishes to emphasize the importance of the aggregate in making up the concrete structure. Fine aggregate may be considered as gravel, sand, or screenings from hard, durable rock, graded so that it will pass, when dry, a screen having ¼-in. circular openings. The best fine aggregate is in general that which is graded fairly uniformly from the ¼-in. size mentioned above, downward, but not more than 5% should be of such fineness that it will pass a sieve having 100 meshes per lin. in. A preponderance of the coarser particles rather than the finer is desirable, and in any case less than 3% of the material should pass the 200-mesh sieve. The strength of standard briquettes, made of samples of fine aggregate and tested at the usual periods of 7 and 28 days, should show a strength at least equal to similar briquettes made of the same cement and three parts of standard Ottawa sand. Coarse aggregate, in general, should not be larger than such as will pass a screen with 1½-in. circular openings, ranging down fairly uniformly from this size to that which will be retained on a ¼-in. screen. The percentage of loss of such material, as determined by the abrasion test, should not be more than 5 per cent.

A denser and more uniform concrete may be made by screening the material, both fine and coarse aggregates, into different sizes and recombining these different sizes in such a way as will give the densest mixture, that is the smallest percentage of voids, when dry. Although this adds somewhat to the expense, the resulting composition will generally be found enough better to make up for the additional expenditure. Furthermore, in proportioning the ingredients of the concrete, a mixture based on mechanical analyses is in general to be preferred to the arbitrary rule of a 1:2:4 or 1:3:5 mix. The slight increase in time and expense which is incurred by determining the voids and combining the various sizes to get the greatest density is more than repaid by the strength and density of the resulting mixture. Similar care in the determination of the proper quantity of water is also to be desired in order that the concrete may have a uniform consistency as it is deposited in place. Though the mixture should be rather wet, especially if it is deposited without tamping, it should still be stiff enough to hold its shape when struck off by the template, and yet not result in segregation of the different sizes

* *Proceedings*, Am. Soc. C. E., for February, 1913.

throughout the mass. Water used in mixing should be clean and free from oil, alkali, or vegetable matter.

Construction.—Forms used in cement-concrete pavements should be as carefully considered as those for any other class of structural work in concrete. It is important that they be true, and free from warp, and of sufficient strength to hold the wet concrete without springing out of shape. Particular care should be taken to keep the forms tight, so that leakage through the sides, which will allow the cement or mortar to be carried out of the coarse aggregate along the edges of the roadway, may be effectively prevented. The concrete should be deposited rapidly on the sub-grade to the required depth and to the entire width of the pavement. It is better to have the surface of the rolled and finished sub-grade thoroughly dampened before beginning to deposit the concrete. Rolling or ramming the freshly placed concrete is desirable wherever practicable, as it not only increases the density of the resulting mass, but also tends to place the particles of the coarse aggregate on the surface, so that they interlock with each other and present a flat side to the wear of traffic.

Clean vertical joints, straight across the roadway through the entire mass of concrete in place, should be insisted on when the work stops for a day, or if there is a stoppage of more than 30 min. in the work during the day. Special precautions should be taken to prevent freezing when work is carried on during cold weather, and it should be borne in mind that concrete sets much more slowly in cold weather than in warm weather. If, in the course of the work, the temperature reaches, say 40° Fahr. and is falling, the operation of mixing and laying concrete should be suspended, and the newly laid surface suitably protected from frost.

In finishing the surface of the concrete, a template or a striking board should be used, which gives the true form of the finished pavement for its entire width. For the final surface finish the use of the wooden float, operated from a suitable bridge which spans the entire pavement, is necessary. Care should be taken that the final surface of the pavement is true, both transversely and longitudinally, that is, with regard to both cross-section and grade.

Brick and Slag Block Pavements.

General.—The general principles heretofore enunciated will apply to brick or slag block pavements, although in some cases they are simplified in the following paragraphs.

The maximum grade of 6% heretofore given is intended to apply to pavements with cement mortar joints; where bituminous joints are used, or where the brick or blocks are specially designed to prevent slipping, grades as high as 12% may be used. With special "hillside" brick, bituminous joints should always be used.

Artificial Foundation.—Owing to the inelastic nature of brick and slag block pavements, the surface of the wearing course must be smooth and true to contour, to insure ease of traction, comfortable riding, and the integrity of the surface, particularly where cement joints are used. Special care, therefore, should be taken to provide a concrete foundation of ample strength and with a surface parallel with that of the wearing course. The minimum of 4 in. for the thickness of the artificial foundation should be used only when the brick or blocks are bedded in cement mortar on a concrete foundation resulting in a monolithic pavement approximately 8 in. in thickness, or when the natural foundation affords good drainage and is firm and unyielding. There may be conditions under which the concrete foundation can be entirely dispensed with, but this is only justified where, owing to the low first cost of the brick, exceptionally good bearing qualities of the soil, light traffic, and lack of funds to provide a more substantial road surface, brick laid with sand joints and without an artificial foundation may be used as the first step in road improvement. If the roadway is not kept clean, the material which accumulates on the surface of the wearing course will protect it from injury, and its function will then be simply to provide a foundation for an earth road.

Cushion Course.—The function of the cushion between the brick or block and the artificial foundation of concrete is to give resiliency to the wearing course and to allow for irregularities in the surface of the concrete and for unavoidable variations in the depth of the brick or block. If the surface of the concrete foundation is made true to the adopted cross-section, as the variation of the depth of the brick or block decreases, the thickness of the sand cushion may be correspondingly decreased. The desirable resiliency will be secured by a sand cushion 1 in., or even slightly less, in depth, provided that depth is uniform, and if the surface of the concrete foundation is truly parallel with the finished pavement; and, if the variation in the depth of the brick or blocks does not exceed $\frac{1}{8}$ in., the thickness of the sand cushion can safely be reduced to $\frac{3}{4}$ in. In a number of brick pavements recently laid, the cushion course has been dispensed with entirely, the brick having been bedded in cement mortar spread over the concrete foundation. This results in a monolithic structure less capable of absorbing shock than is the case where a sand or bituminous cushion is interposed between the wearing surface and the foundation, and the joints are filled with a bituminous filler. A cushion course composed of sand or stone chips and a bituminous cement from $\frac{1}{4}$ to $\frac{1}{2}$ in. in thickness may be substituted for sand or cement mortar, provided the surface of the concrete foundation is made sufficiently smooth and regular in contour.

Materials.—The quality of the brick or block should be determined by physical tests, and the standard rattler test, recommended by the National Association of Paving Brick Manufacturers and adopted by the American Society for Testing Materials, is approved by the Committee. This test will indicate the toughness and resistance to wear from shock and abrasion. Uniformity in the rate of wear is so important that it properly may be a controlling consideration, even at the expense of a moderate increase in the rate of wear. Absorption is readily determined by immersion in water. In size and shape it is desirable to conform to accepted standards, in order that repairs and renewals may more readily be made. Uniformity in size is especially important, and variations in depth should be kept within the narrowest limits, for reasons heretofore given under "Cushion Course".

Construction.—The brick or block should be laid in straight courses at right angles to the axis of the roadway, although at intersections they may advantageously be laid in diagonal courses arranged so that traffic turning any of the corners will move across and not along the continuous joints. They should be laid so that the joints shall be uniform in width and of sufficient width only to permit the filler to reach the bottom of the joints. Lug bricks have the advantage of insuring such uniform joints, with ordinary care in laying. If a sand cushion is used great care should be taken to avoid any disturbance of the surface of the cushion after it shall have been brought to true grade by using a template. If bedded in a mortar or bituminous cushion, the brick or block should be bedded so that the surface shall be as true as possible. In all cases the brick after being laid should be brought to a true and even surface by the use of a roller.

Stone Block Pavements.

Materials.—The stone pavements of this country are generally of granite or sandstone, the particular kind being determined by the availability of the different materials. Limestone is used to a certain extent in one or two cities, but so slightly that it need not be considered.

In order to make a good paving block, stone should be resistant to wear, hard and tough, and of such a character as to be easily broken into regular shapes. Toughness is more important than hardness, as in very few cases will the blocks of a stone pavement of a character such as is generally used be much reduced under actual traffic. The quantity of wear is not as important as that the wear shall be uniform, so that the surface of the pavement may be kept smooth and even.

The character of sandstone is such that, though it does wear smooth, it is never slippery; but with granite, if the stone is too hard,

even when no particular wear is noticed under traffic, the surface soon becomes smooth and slippery, and the harder the stone the more slippery it becomes.

To make suitable paving blocks, granite should be a medium and uniform grained stone, of such a character that when broken it will present smooth and even surfaces, and have a percentage of wear of not more than 4.5 and toughness of not less than 8. It should have a crushing strength of not less than 20 000 lb. per sq. in.

Sandstone should be hard and tough, and of a character to meet the requirements given for granite, except as to crushing strength, which should be not less than 16 000 lb. per sq. in.

As the stone must be made into comparatively small blocks, and as this is done by expensive labor, the size of the blocks is extremely important. Probably the ideal sized block would be 8 in. long, $3\frac{1}{2}$ in. wide, and, under general conditions, 5 in. deep, but if blocks were made to conform exactly to these dimensions, they would be extremely expensive, so that it is considered good practice to allow variations in length from 8 to 12 in., in width from $3\frac{1}{2}$ to $4\frac{1}{2}$ in., and in depth from $4\frac{3}{4}$ to $5\frac{1}{4}$ in. When sandstone is used, the blocks can be a little wider, as far as use is concerned. All blocks, however, should be sorted, so that the adjacent courses can be kept as nearly uniform in width as possible. Under no circumstances, however, should blocks of different widths be used in the same course. The blocks should be dressed so that they will lie with close joints, and have good, smooth, and even heads.

Another form of stone block pavement, used to some extent in Europe, and which has recently been introduced into this country, is known as "Durax" in England and as "Kleinpflaster" in Germany. It consists of blocks approximating cubes $2\frac{1}{2}$ to 4 in. in size, although they should not be exactly cubical; they should be sufficiently irregular, both in size and shape, to permit them to be laid in arcs of circles of comparatively small radii and so that the joints will not be excessively large. By laying the courses in circular arcs, none of the joints is parallel to any line of traffic.

In Europe these blocks are used to a great extent in resurfacing the broken stone roads where the traffic is too heavy for the macadam, and to some extent in city streets. If the blocks can be produced in this country at a reasonable price, they will make very satisfactory roads. They have been used to a slight extent in pavements in some Southern cities.

During the last few years many pavements have been laid of granite blocks made by splitting up old ones which had been in use for some years. With blocks that ranged from 4 to 5 in. in width, 10 to 12 in. and even 14 in. in length, and 8 in. in depth, it has been found possible to get many good blocks of smaller size by cutting them up.

The new blocks, being small, could be cut to a reasonably true surface without much work, with the result that the old blocks recut would actually lay more square yards in a pavement than the original ones. This practice is to be commended, both on the score of economy and result.

Foundation and Cushion.—It is assumed that the foundation for permanent stone pavements will in all cases be concrete. On the concrete must be spread a material to act both as a cushion to the blocks themselves and to even up the surface of the concrete; and the smoother the surface and the less the variation in the depth of the blocks, the thinner can be the cushion, although it should not be less than $\frac{3}{4}$ in., in any event.

The cushion which has generally been used for this purpose is sand, but recently engineers have been considering the advisability of using Portland cement mortar instead. The objection to mortar, made by some, is that it makes a too solid base for the blocks, not giving any resiliency. This at present is a mooted question, and the Committee does not desire to express a positive opinion as to the relative values of the two. If a good bituminous cushion could be provided, it would probably be more satisfactory than either the mortar or the sand, but it is questionable if the advantage gained would justify the increase in expense. (See also Brick and Slag Block Pavements.)

Construction.—The blocks should be laid on the cushion stone to stone, keeping the joints as small as possible. The joints should be filled with water-proof material. For this purpose a Portland cement grout, asphalt, or some other bituminous filler is generally used, and in some cases sand is mixed with a bituminous material in order to increase the toughness of the filler. All these fillers give good results, but with cement grout the cost of taking up and restoring the pavement over cuts is increased over that of a bituminous filler, as in many cases blocks are broken in taking them up, and it is difficult to clean the cement from the individual blocks and also to keep the traffic from the cut or patch while the grout is setting after the pavement has been restored. Another disadvantage of the cement grout filler is that it is highly important that it be perfectly set before traffic is allowed on the pavement, and in large cities it is almost impossible to keep traffic from the pavement, after it is laid, for the necessary length of time.

Wood Block Pavements.

General.—In using wood in pavements, special attention should be given to the crown of the street, as this material undoubtedly presents, under certain conditions, a more slippery surface to traffic than any other. Wherever the longitudinal grade is sufficient to allow the

water to run off freely, the crown should be very flat, not exceeding 3 in. in a roadway width of 30 ft. On streets that must be used continuously, the maximum grade allowed should not exceed 2%, although on residence streets, where pavements can be avoided when they are exceptionally slippery, grades up to 3 or 4% are permissible.

Kinds of Wood for Blocks.—It is generally accepted that, whatever the kind of wood used for pavements, it must be treated with some preservative, in order to make it suitable. It is important that as many kinds of wood be used as possible, so that in any territory the most available one can be used. Just how many varieties can be utilized is uncertain at the present time, but those that are undoubtedly good are: Southern yellow pine, Douglas fir, tamarack, Norway pine, hemlock, and black gum. In the East and Central West, Southern yellow pine, and on the Pacific Coast, Douglas fir, are generally used. Experiments will be necessary to determine just what other kinds will be satisfactory.

The blocks must be sound, and must be well manufactured, square-butted, square-edged, free from unsound, loose or hollow knots, knot holes, worm holes, and other defects, such as shakes, checks, etc., that would be detrimental to the blocks.

The number of annual rings in the 1 in. which begins 2 in. from the pith of the block should not be less than 6, measured radially, provided, however, that blocks containing between 5 and 6 rings in this inch may be accepted if they contain $33\frac{1}{3}$%, or more of summer wood. In case the block does not contain the pith, the 1 in. to be used shall begin 1 in. away from the ring which is nearest to the heart of the block. The blocks in each charge shall contain an average of at least 70% of heart wood. No one block shall be accepted that contains less than 50% of heart wood.

Size of Blocks.—The blocks should be from 5 to 10 in. long, but should preferably average two times the depth; they should be ... in.* in depth. They may be from 3 to 4 in. in width, but in any one city block all of them should be of uniform width. A variation of $\frac{1}{16}$ in. should be allowed in the depth and $\frac{1}{8}$ in. in the width of the blocks from that specified. In all cases the width should be greater or less than the depth by at least $\frac{1}{4}$ in.

Preservatives for Wood Blocks.—Many different materials have been used in the past for wood preservatives, but it seems to be admitted generally that, taking all things into consideration, coal-tar creosote oil is the best. As the object of the preservative is not only to prevent the blocks from decay, but also to prevent them from swelling in wet weather or shrinking in dry weather, whatever the

* The Committee recommends blocks 4 in. in depth for very heavy traffic streets; blocks $3\frac{1}{2}$ in. in depth for moderate traffic streets. For light traffic streets blocks 3 in. in depth may be used, but where 3-in. blocks are used, no blocks should be longer than 8 in.

preservative, it should be of a character that will render the blocks stable and free from decay, for as long a time as possible. It is probable that under the traffic that prevails on most of the streets paved with wood in this country, if the blocks can be kept stable and free from decay, the pavement will last from 30 to 35 years, or even longer. It is necessary, however, to have an oil that is in itself stable and will remain in the blocks a long time.

It is thought that a heavy gravity oil will do this better than one of light gravity, as the former is less volatile and will maintain its condition better while exposed to atmospheric changes. The Committee recognizes that good results have been obtained by the use of a pure distillate oil and also one which contains a certain quantity of coal-gas tar. These two oils should conform to the following requirements:

Distillate Oil.—The oil shall be a distillate of coal-gas tar or coke-oven tar. It shall comply with the following requirements:

1. It shall not contain more than 3% of water.
2. It shall not contain more than 0.5% of matter insoluble in benzol.
3. The specific gravity of the oil at 38° cent. (100° Fahr.) shall be not less than 1.06.
4. The distillates based on water-free oil shall be within the following limits:

   Up to 210° cent., not more than 5 per cent.
   Up to 235° cent., not more than 15 per cent.

   The residue above 355° cent., if it exceeds 10%, shall have a float test of not more than ....* sec. at 0° cent.
5. The specific gravity of the fraction between 235° cent. and 315° cent. shall be not less than 1.02 at 38°/15.5° cent. (100°/60° Fahr.).

   The specific gravity of the fraction between 315° cent. and 355° cent. shall be not less that 1.09 at 38°/15.5° cent. (100°/60° Fahr.).
6. The oil shall yield not more than 2% coke residue.

Coal-Tar Paving Oil.—The oil shall be a coal-tar product of which at least 65% shall be a distillate of coal-gas tar or coke-oven tar, and the remainder shall be refined or filtered coal-gas tar or coke-oven tar, to comply with the following requirements:

1. It shall not contain more than 3% of water.
2. It shall not contain more than 3% of matter insoluble in benzol.
3. The specific gravity of the oil at 38° cent. (100° Fahr.) shall be not less than 1.07 nor more than 1.12.

* It was understood that the blanks left in the requirements for the float test would be filled in when the results of experiments being made by the Committee on Preservatives, of the American Wood Preservers' Association, were known.

4. The distillates based on water-free oil shall be within the following limits:

   Up to 210° cent., not more than 5 per cent.
   Up to 235° cent., not more than 25 per cent.

   The residue above 355° cent., if it exceeds 35%, shall have a float test of not more than ....* sec. at 100° cent.
5. The specific gravity of the fraction between 235° cent. and 315° cent. shall be not less than 1.02 at 38°/15.5° cent. (100°/60° Fahr.).

   The specific gravity of the fraction between 315° cent. and 355° cent. shall be not less than 1.09 at 38°/15.5° cent. (100°/60° Fahr.).
6. The oil shall yield not more than (?) residue.

Some engineers, however, feel that a creosote oil produced from water-gas tar is as good as one produced from coal-gas tar, if not better. Though the Committee does not have this feeling, it does suggest the following requirements for water-gas tar oil, if it should be used:

1. The preservative oil shall be a product of water-gas tar, and free from admixture of other crude or unrefined tars.
2. The specific gravity at 38° cent. (100° Fahr.), compared with water at the same temperature, shall be between 1.11 and 1.14.
3. Material insoluble by hot continuous extraction with benzol or chloroform shall not exceed 2% by weight.
4. Distillation to 210° cent. shall not exceed 3% by weight.
   " " 235° " " " " 10% " "
   " " 315° " " " " 40% " "
   " " 355° " shall not be less than 25 per cent.
5. Specific gravity of the distillate at 38° cent. (100° Fahr.), compared to 15.5° cent. (60° Fahr.) between 235° cent. and 315° cent., should not be less than 0.96 nor more than 1.00.

Treatment of Wood Blocks.—The timber may be either air-seasoned or green, but should preferably be treated within 3 months from the time it is sawed. Green timber and seasoned timber, however, should not be treated together in the same charge. The blocks should be treated in an air-tight cylinder with the preservative heretofore specified. In all cases, whether thoroughly air-seasoned or green, they should first be subjected to live steam at a temperature between 104° and 160° cent. (220° and 240° Fahr.)† for not less than 2 hours nor more than 4 hours, at the discretion of the treating plant operator,

* It was understood that the blanks left in the requirements for the float test would be filled in when the results of experiments being made by the Committee on Preservatives, of the American Wood Preservers' Association, were known.

† In no case should a steam pressure of 20 lb. per sq. in. be exceeded.

after which they should be subjected to a vacuum of not less than 22 in., held for at least 1 hour. While the vacuum is still on, the preservative oil, heated to a temperature of between 82° and 104° cent. (180° and 220° Fahr.) should be run in until the cylinder is completely filled, care being taken that no air is admitted. Pressure should then be gradually applied, not to exceed 50 lb. at the end of the first hour nor 100 lb. at the end of the second hour, and then maintained at not less than 100 nor more than 150 lb. until the wood has absorbed the required quantity of oil.*

After this a supplemental vacuum, in which the maximum intensity reached is at least 20 in. and the time the vacuum is applied not less than 30 min., should be applied. If desired, this vacuum may be either preceded or followed by a short steaming period.

In any charge blocks should contain at least 16 lb. of water-free oil per cu. ft. of wood at the completion of the treatment. The blocks after treatment should show satisfactory penetration of the preservative, and in all cases the oil must be diffused throughout the sapwood. To determine this, at least 25 blocks shall be selected from various parts of each charge and sawed in half perpendicular to the fibers through the center, and if more than one of these blocks shows untreated sapwood, the charge should be re-treated. After re-treating, the charge should be again subjected to a similar inspection.

The surface of the blocks after treatment should be free from deposits of objectionable substances, and all blocks that have been materially warped, checked, or otherwise injured in the process of treatment should be rejected.

Handling Blocks after Treatment.—Blocks should preferably be laid in the street as soon as possible after being treated. If they cannot be laid immediately, provision should be made to prevent them from drying out by stacking in close piles and covering them, and, if possible, by sprinkling them thoroughly at intervals. In any case, where they are not laid as soon as they are received on the street, they should be well sprinkled about 2 days before being laid, under the direction of the purchaser. It is important to have the wood sufficiently wet to be swelled to its maximum size before it is laid.

Inspection.—All material herein specified and processes used in the manufacture of the blocks therefrom should be subject to inspection, acceptance, or rejection at the plant of the manufacturer, which should be equipped with the necessary gauges, appliances, and facilities to enable the inspector to satisfy himself that the requirements of the specifications are fulfilled.

The purchaser should have the further right to inspect the blocks after delivery on the street, for the purpose of rejecting any blocks

* This treatment is recommended for yellow pine only. It is probably also suited to Norway pine, hemlock, black gum, and tamarack, but not to Douglas fir.

that do not meet these specifications, except that the plant inspections should be final with respect to the kind of wood, rings per inch, oil, and treatment.

Construction.—There are two methods of laying wood blocks, one with and one without a cushion. In Europe it is invariably the practice to lay the blocks directly on the concrete bed. When this is done it is necessary that the surface of the concrete be made absolutely smooth and true to the required cross-section of the pavement. In this country the practice has been to surface-up the concrete, as has been mentioned in connection with stone blocks, with cement mortar or sand. The Committee believes that the cement mortar will give a better result than the sand. It should, however, be mixed as dry as possible and at the same time insure setting, and the blocks should be thoroughly rolled into it. If the sand cushion is used, the blocks should also be rolled to a smooth surface.

The Committee looks with a great deal of favor on the practice of finishing the concrete to a true surface and laying the blocks directly on it, and would suggest that engineers laying this pavement try this method, and, if the cost of producing a smooth concrete surface is not excessive, the method be generally adopted.

The blocks should be laid closely and the joints filled with some suitable material. Three methods have been used in this country for joint filling: sand, cement grout, and a bituminous material. On heavy traffic streets, if fine sand is used, good results will be obtained. On light traffic streets, however, it may be better to use a bituminous filler of practically the same character as that used for granite.

If a bituminous filler is used, the pavement should be covered with a thin layer of fine sand, which should be allowed to remain 1 or 2 weeks after the traffic has been allowed on the street.

The Committee does not feel that cement grout should be used in any case.

Though a wood block pavement should keep stable, it is undoubtedly safer to use a bituminous joint along the curb to provide for expansion or contraction.

Bleeding.—Considerable inconvenience has been caused in certain cities by "bleeding", or the exudation of the preservative on the surface of the street, after the blocks have been laid. If the proper precaution is taken with the character of the material and the character of the treatment, it is thought that this can be avoided. If the pavement, however, should bleed to such an extent as to be a nuisance, it should be covered with fine sand, so that the surface material can be absorbed. After one or two applications there should be no further trouble.

The Committee wishes to express again its deep appreciation of the assistance rendered it by the Board of Direction and by your

Secretary, Mr. Chas. Warren Hunt, as well as by members of the Society, and others,

Very respectfully,

For the Special Committee on
"Materials for Road Construction and on Standards for Their Test and Use."

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PAPERS AND DISCUSSIONS

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PROGRESS REPORT OF THE SPECIAL COMMITTEE ON STEEL COLUMNS AND STRUTS*

To the American Society of Civil Engineers:

The Special Committee, authorized by vote of this Society, "to consider and report upon the design, ultimate strength, and safe working values of steel columns and struts", presents the following report of progress.

During the past year, your Committee has held five regular meetings, and the minutes of these meetings have been sent to the Board of Direction for publication in the *Proceedings*.

The last Progress Report of your Committee gave a list of eighteen Carnegie, mine section, H-columns. These columns were donated to the Bureau of Standards for testing purposes in connection with the Committee's programme. These mine sections are rolled only in one light-weight cross-section, so there is no opportunity for comparing the results for various thicknesses of metal, as in the other column types. An abstract of the results of the tests on these columns is shown in Table 1.

The experimental work of the Bureau of Standards of the U. S. Government at Washington, S. W. Stratton, Director, has made steady progress, and a large part of the work of your Committee has been spent in co-operation with the Bureau, in following up the results of the tests, and in determining the details of future procedure.

In the last Progress Report of the Committee, mention was made of three lines of investigation which were being prosecuted by means of supplementary tests. These tests have been made, and the results are herewith presented.

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* To be presented to the Annual Meeting, January 17th, 1917.

1.—On pages 2763 and 2764 of the *Proceedings* for December, 1915, mention was made of short columns, slenderness ratio of $\frac{l}{r} = 20$, which were cut from longer columns that had already been tested to their ultimate strength, and it was stated that your Committee did not care to draw conclusions until tests could be made on columns which had not been previously stressed.

The Bureau of Standards ordered six plate and angle columns, slenderness ratio of $\frac{l}{r} = 20$, Type 1, three of light section and three of heavy section. The abstract of the test results is shown in Table 1, but it will be seen that this abstract, like that of last year, does not tell the whole story. The stress-strain diagrams for these six columns are shown in Fig. 1, and when they are compared with the stress-strain diagrams shown in the report of last year, it will be seen that approximately the same relative difference exists between the yield points of the light and heavy material.

2.—Attention was called, in the last report, to the uniform difference in ultimate strength between the columns of light and heavy sections, and additional test columns were ordered by the Bureau of Standards, to learn whether the reduction in ultimate strength in the heavy sections was progressive as the thickness of the material increased. As was noted, a full set of three columns of each of the three slenderness ratios $\frac{l}{r} = 50$, 85, and 120 was chosen for Type 5, which is a Bethlehem **H**-section, with a nominal area of 26.64 sq. in. An abstract of the test records of these extra heavy Bethlehem columns is shown in Table 2. It also shows the abstract of the light and heavy Bethlehem sections, which were tested and recorded last year.

One set of extra heavy columns, Type 1, which are plate and angle **I**-shape columns, with a nominal area of 28.61 sq. in., was ordered with slenderness ratio of $\frac{l}{r} = 85$, which, as will be remembered, was the average of the three ratios originally provided. An abstract of the results of the tests on these three columns is contained in Table 3, in which is shown for comparison the results of the tests made last year on light and heavy section columns, Type 1.

It will be noted that the extra heavy Bethlehem columns show a marked falling off in ultimate strengths for all three of the slenderness ratios, while the extra heavy plate and angle columns, for which there was only one slenderness ratio, show very little reduction in strength when compared with the heavy sections tested last year.

3.—Table 4 shows the abstract of the results of the tests of the columns with slenderness ratio $\frac{l}{r} = 155$. The records of these tests

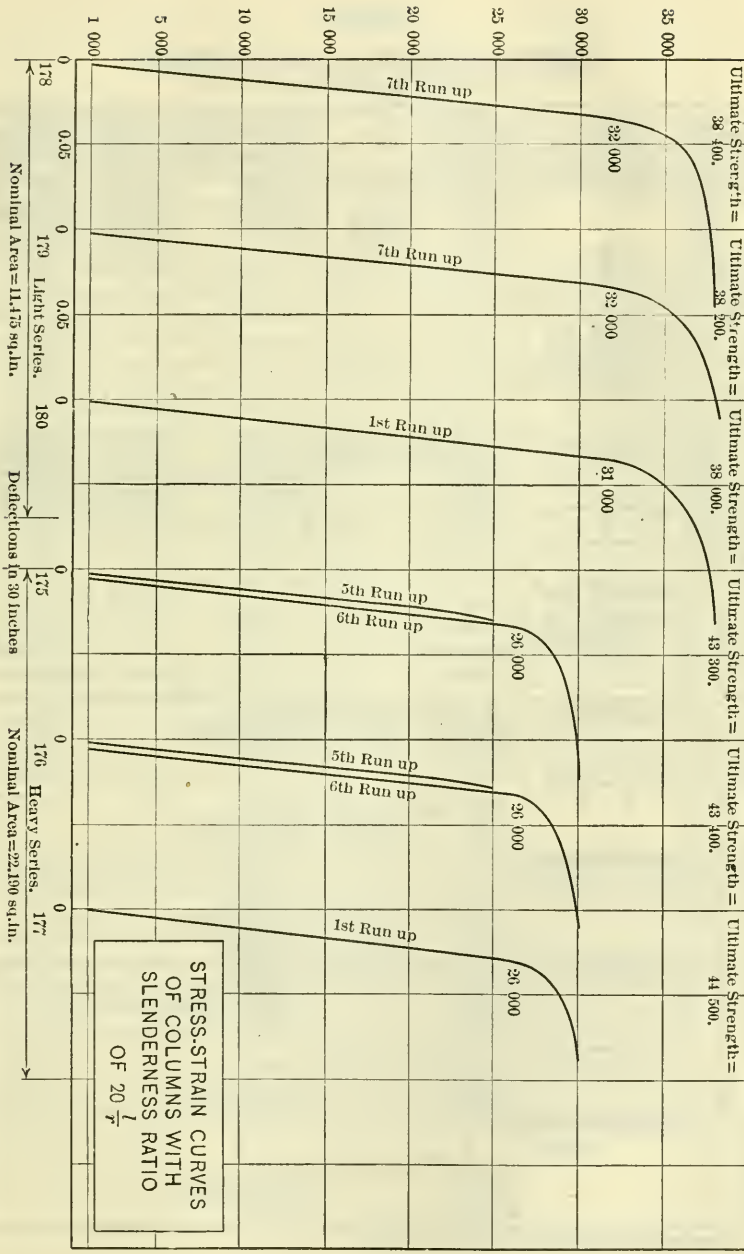

STRESS-STRAIN CURVES
OF COLUMNS WITH
SLENDERNESS RATIO
OF 20 $\frac{l}{r}$
Ultimate Strength = 38 400.
Ultimate Strength = 38 200.
Ultimate Strength = 38 000.
Ultimate Strength = 43 300.
Ultimate Strength = 43 400.
Ultimate Strength = 44 500.
7th Run up
7th Run up
1st Run up
5th Run up
6th Run up
5th Run up
6th Run up
1st Run up
32 000
32 000
31 000
26 000
26 000
26 000
1 000
5 000
10 000
15 000
20 000
25 000
30 000
35 000
0
0.05
178
179
180
175
176
177
Light Series.
Heavy Series.
Nominal Area=11.475 sq.in.
Nominal Area=22.190 sq.in.
Deflections in 30 inches

FIG. 1.

TABLE 1.

ABSTRACT OF RECORD OF COLUMN TESTS.
TYPES I & IA AND CARNEGIE SECTIONS.

Type	Test no.	Section.	Actual Area	Radius of Gyration	Length	$\frac{l}{r}$	Unit Ultimate Strength	Average Ultimate Strength	Deflection in inches at the Middle of Columns at the Reading just before Failure.	
I	178	Light Sections.	11.93	2.24	3'-8$\frac{11}{16}$"	20	38400		0.0261 S.	0.0261 Up.
	179		11.81	"	"	"	38200	38200	0.0040 N.	0.0580 Down.
	180	4L^s 5"x3"x$\frac{5}{16}$" = 9.60□" 1 Pl. 6"x$\frac{5}{16}$" = 1.875 Total = 11.475□"	11.79	"	3'-8$\frac{3}{4}$	"	38000		0.0068 S.	0.0042 Down.
IA	175	Heavy Sections.	22.26	2.36	3'-11$\frac{1}{16}$"	20	43200		0.0282 N.	0.0032 Down.
	176		22.33	"	"	"	43300	43600	0.0578 N.	0.1023 Down.
	177	4L^s 5"x3"x$\frac{5}{8}$" = 18.44□" 1 Pl. 6"x$\frac{5}{8}$" = 3.75 Total = 22.19□"	22.33	"	"	"	44300		0.0385 N.	0.0462 Up.
		Light Sections.	7.00	1.45	6'-0$\frac{7}{16}$"	50	31500			
			7.00	"	6'-0$\frac{1}{2}$"	"	30000	31000		
			7.00	"	"	"	31400			
			7.00	1.45	10'-3$\frac{1}{4}$"	85	30600			
			7.00	"	10'-3$\frac{3}{16}$"	"	30000	30400		
		Carnegie 6" H Col. x 23.8-lb. = 7.00□"	7.00	"	10'-3$\frac{1}{4}$"	"	30500			
			7.00	1.45	14'-6"	120	26400			
			7.00	"	14'-6$\frac{3}{16}$"	"	29300	27200		
			7.00	"	14'-6"	"	26000			
		Light Sections.	10.00	1.87	7'-9$\frac{1}{2}$"	50	32800			
			10.00	"	7'-9$\frac{3}{8}$"	"	33900	33500		
			10.00	"	"	"	33800			
			10.00	1.87	13'-3"	85	31800			
			10.00	"	"	"	31000	31700		
		Carnegie 8" H Col. x 34.0-lb. = 10.00□"	10.00	"	"	"	32300			
			10.00	1.87	18'-8$\frac{1}{2}$"	120	30000			
			10.00	"	"	"	28900	29200		
			10.00	"	"	"	28700			

Areas given for Carnegie Sections are nominal.

TABLE 2.

ABSTRACT OF RECORD OF COLUMN TESTS.

TYPES 5, 5A & 5B.

Type.	Test no.	Section.	Actual Area.	Radius of Gyration	Length.	$\frac{l}{r}$	Unit Ultimate Strength.	Average Ultimate Strength.	Deflection in inches at the Middle of Columns at the Reading just before Failure.	
		LIGHT AND HEAVY SECTIONS.								
5	107	Light Sections.	9.62	1.98	8′–3″	50	38000		0.0280 N.	0.0115 Down.
	122		9.65	"	"	"	38000	38000	0.0836 N.	0.0287 Down.
	123	A A	9.65	"	"	"	38000		0.0052 S.	0.0209 Down.
	114		8.61	"	14′–0 5/16″	85	36000		0.1510 S.	0.0078 Down.
	116		9.66	"	"	"	34000	34300	0.1148 S.	0.0085 Up.
	119	Beth. 8″ H Col. x 32-lb.	9.59	"	"	"	33000		0.1201 S.	0.0376 Up.
		= 9.17□″								
	110		8.64	"	19′–9 5/8″	120	33900		0.1148 N.	0.0084 Up.
	111		8.68	"	"	"	31000	32000	0.2140 N.	0.0136 Down.
	108		8.61	"	"	"	31000		0.1806 S.	0.0110 Up.
5A	106	Heavy Sections.	17.86	2.09	8′–8½″	50	34000		0.1201 N.	0.0084 Up.
	120		17.82	"	"	"	36100	35400	0.0606 N.	0.0016 Up.
	121	A A	17.86	"	"	"	36000		0.0284 N.	0.0033 Up.
	115		18.05	"	14′–9 5/8″	85	33900		0.0521 N.	0.0151 Down.
	117		17.73	"	"	"	32000	32300	0.0929 N.	0.0054 Down.
	118	Beth. 8″ H Col. x 62-lb.	17.77	"	"	"	31000		0.0470 S.	0.0277 Up.
		= 18.27□″								
	109		17.76	"	20′–10 13/16″	120	30000		0.1498 N.	0.0037 Up.
	112		17.97	"	"	"	30000	30000	0.2401 S.	0.0219 Down.
	113		17.73	"	"	"	30000		0.1610 N.	0.0221 Down.
		EXTRA HEAVY SECTIONS.								
5B	225	Extra Heavy Sections	27.49	2.17	9′–0½″	50	24000		0.0825 S.	0.0104 Down.
	226		27.18	"	"	"	24600	25200	0.1044 S.	0.0261 Down.
	182	A A	27.50	"	"	"	27100		0.0522 N.	0.0033 Up.
	227		27.28	"	15′–4 7/16″	85	22600		0.2297 N.	0.0438 Down.
	228		27.27	"	"	"	23000	23500	0.0731 S.	0.0078 Up.
	183	Beth. 8″ H Col. x 91-lb.	27.45	"	"	"	24800		0.0553 S.	0.0016 Down.
		= 26.64□″								
	223		27.50	"	21′–8 3/8″	120	21000		0.3341 S.	0.0113 Up.
	224		27.54	"	"	"	21000	21300	0.2610 S.	0.0459 Up.
	181		27.57	"	"	"	21800		0.1903 S.	0.0031 Up.

TABLE 3.

ABSTRACT OF RECORD OF COLUMN TESTS.

TYPES I, IA & IB.

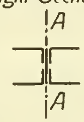
Type.	Test no.	Section.	Actual Area	Radius of Gyration	Length.	$\frac{l}{r}$	Unit Ultimate Strength.	Average Ultimate Strength.	Deflection in inches at the Middle of Columns at the Reading just before Failure.	
		LIGHT AND HEAVY SECTIONS.								
	8	Light Sections.	11.13	2.24	9'-4"	50	32400		0.0350 S.	0.0000
	38		11.17	"	"	"	32800	32700	0.0700 S.	0.1000 Up.
	77		11.13	"	"	"	33000		0.0500 N.	0.0313 Up.
	18		11.49	"	15'-10 7/16"	85	32100		0.1200 S.	0.0500 Up.
I	84		11.49	"	"	"	31400	31200	0.0252 S.	0.1281 Down.
	85	4Lˢ 5"x3"x5/16" = 9.60□"	11.35	"	"	"	30000		0.0626 N.	0.1368 Up.
		1 Pl. 6"x5/16" = 1.875								
	30	Total = 11.475□"	11.20	"	22'-4 13/16"	120	28600		0.0000	0.0600 Down.
	56		11.14	"	"	"	27600	28300	0.1175 S.	0.1091 Up.
	69		11.30	"	"	"	28700		0.0135 N.	0.1785 Down.
	93	Heavy Sections.	22.25	2.36	9'-10"	50	29000		0.0080 S.	0.0574 Down.
	96		22.13	"	"	"	28900	29200	0.0731 N.	0.0457 Up.
	97		22.28	"	"	"	29700		0.0653 N.	0.0002 Up.
	91		22.134	"	16'-8 5/8"	85	28000		0.0475 S.	0.0883 Up.
IA	94		21.92	"	"	"	28200	28100	0.4053 N.	0.2636 Up.
	95	4Lˢ 5"x3"x5/8" = 18.44□"	22.05	"	"	"	28000		0.0764 N.	0.0825 Down.
		1 Pl. 6"x5/8" = 3.75								
	92	Total = 22.19□"	22.15	"	23'-7 3/16"	120	25000		0.1430 S.	0.2923 Down.
	98		22.10	"	"	"	25500	25400	0.3863 N.	0.0762 Up.
	99		22.10	"	"	"	25800		0.1326 N.	0.0606 Down.
		EXTRA HEAVY SECTIONS.								
		Extra Heavy Sections								
										
	229		28.43	2.29	16'-2 5/8"	85	28200		0.0668 N.	0.0167 Down.
IB	230		28.37	"	"	"	27000	27700	0.0900 S.	0.0475 Down.
	231	4Lˢ 5"x3"x13/16" = 23.36□"	28.53	"	"	"	28000		0.0691 N.	0.0007 Up.
		1 Pl. 6"x7/8" = 5.25								
		Total = 28.61□"								

TABLE 4.

ABSTRACT OF RECORD OF COLUMN TESTS.

TYPES 1 & 1A – 2 & 2A – 4 & 4A.

Slenderness Ratio $\frac{l}{r}=155$.

Type	Test no.	Section.	Actual Area.	Radius of Gyration	Length.	$\frac{l}{r}$	Unit Ultimate Strength.	Average Ultimate Strength.	Deflection in inches at the Middle of Columns at the Reading just before Failure.	
		Light Sections.								
1	207		11.84	2.24	28′-11 3/16″	155	27000		0.4176 S.	0.2506 Up.
	218	A	11.69	"	"	"	25600	26200	0.1629 S.	0.6277 Down.
	222	4 Ls 5″×3″×5/16″ = 9.60 □″	11.68	"	"	"	26000		0.1201 N.	0.3289 Down.
		1 Pl. 6″×5/16″ = 1.875								
		Total = 11.475 □″								
		Heavy Sections.								
1A	205	A – A	22.35	2.36	30′-5 13/16″	155	22200		0.1629 S.	0.3967 Up
	206		22.35	"	"	"	23200	22700	0.0992 S.	0.4594 Down.
	208	4 Ls 5″×3″×5/8″ = 18.44 □″	22.31	"	"	"	22700		0.2514 S.	0.4802 Down.
		1 Pl. 6″×5/8″ = 3.75								
		Total = 22.19 □″								
		Light Sections.								
2	215	3½″	10.39	2.31	29′-10 1/16″	155	26100		0.8352 N.	0.1284 Up.
	217	A	10.42	"	"	"	27800	26500	0.5116 N.	0.0668 Down.
	221	2-6″ [s × 10.5-lb. = 6.18 □″	10.46	"	"	"	25600		0.9271 S.	0.0418 Down.
		2 Pls. 8″×1/4″ = 4.00								
		Total = 10.18 □″								
		Heavy Sections.								
2A	214	3½″	16.75	2.33	30′-1 1/8″	155	24700		0.4959 S.	0.2589 Down.
	216	A	16.87	"	"	"	25000	24900	0.1958 N.	0.6160 Up.
	219	2-6″ [s × 15.5-lb. = 9.12 □″	16.81	"	"	"	25000		0.0428 S.	0.2714 Down.
		2 Pls. 8″×1/2″ = 8.00								
		Total = 17.12 □″								
		Light Sections.								
4	211		11.81	2.38	30′-8 7/8″	155	24000		0.5324 N.	0.0002 Down.
	212	A	11.93	"	"	"	23200	23600	0.7465 N.	0.0491 Down.
	220	2-8″ [s × 11.25-lb. = 6.70 □″	11.84	"	"	"	23500		0.5116 S.	0.0040 Down.
		1-8″ I × 18.00-lb. = 5.33								
		Total = 12.03 □″								
		Heavy Sections.								
4A	209		16.74	2.32	29′-11 5/8″	155	24000		0.1754 S.	0.0569 Up.
	210	A	16.67	"	"	"	23000	23300	0.2453 S.	0.0512 Up.
	213	2-8″ [s × 18.75-lb. = 11.02 □″	16.33	"	"	"	23000		0.1973 S.	0.0063 Up.
		1-8″ I × 20.50-lb. = 6.03								
		Total = 17.05 □″								

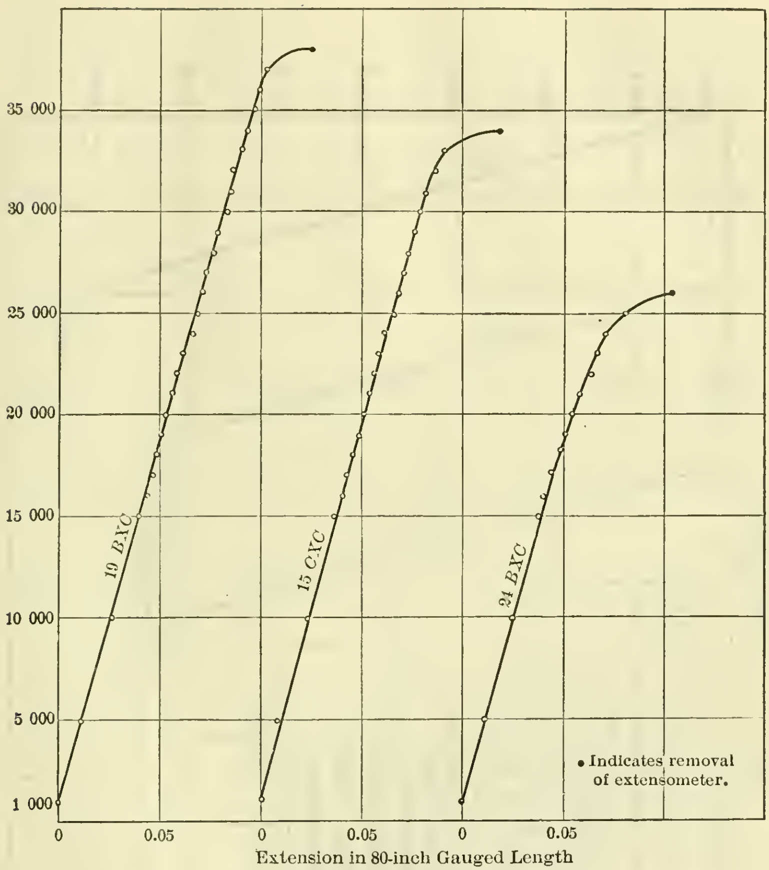
have only just come to hand, and your Committee publishes them without comment.

These three lines of investigation, made by the Bureau of Standards, complete the tests of all the columns ordered on the original and supplementary programmes, with the exception of three columns, Type 1, ordered with the idea of beginning a preliminary investigation concerning eccentric loads. In this investigation, however, the problems which have been presented by the tests thus far made, have produced so many complications that your Committee has not had opportunity to do more than to ask the Bureau of Standards to study the question of the procedure necessary to test the effect of eccentrically loaded columns.

The tables presented herewith and those heretofore presented include abstracts of the results of all these tests, with the exception of a number of supplementary tests made by the Bureau of Standards, in an endeavor better to interpret the results, on columns cut from longer columns previously tested. Your Committee has not deemed it necessary to make an abstract of these supplementary tests, for the reason that they are short columns, of which the ultimate strength is hardly a factor.

Probably the most marked feature of the column investigation of the Bureau of Standards, as reported last year, was the decrease in unit ultimate strength of the heavy sections, when compared with the light sections. This rule, with a single exception, was true for all of the different types of columns, and this exception was easily explained from the fact that Type 6 was not a satisfactory form of column. The Bureau of Standards has been carrying on a series of experiments with the material from which these columns were made, and has been making specimen tests, both in compression and tension, in the effort to determine whether a difference in the metal itself would account for the difference in strength of the columns, or if it is due to shape or other characteristic of the form. These specimen tests have been made with great care, and require considerably more time than the ordinary commercial tension tests. The compression tests on thin webs must be made by building up a little column, composed of several thicknesses clamped together. The arrangement of these pieces, the truing of the ends, and the location of the strain gauges all involve scientific, exacting work, and require time.

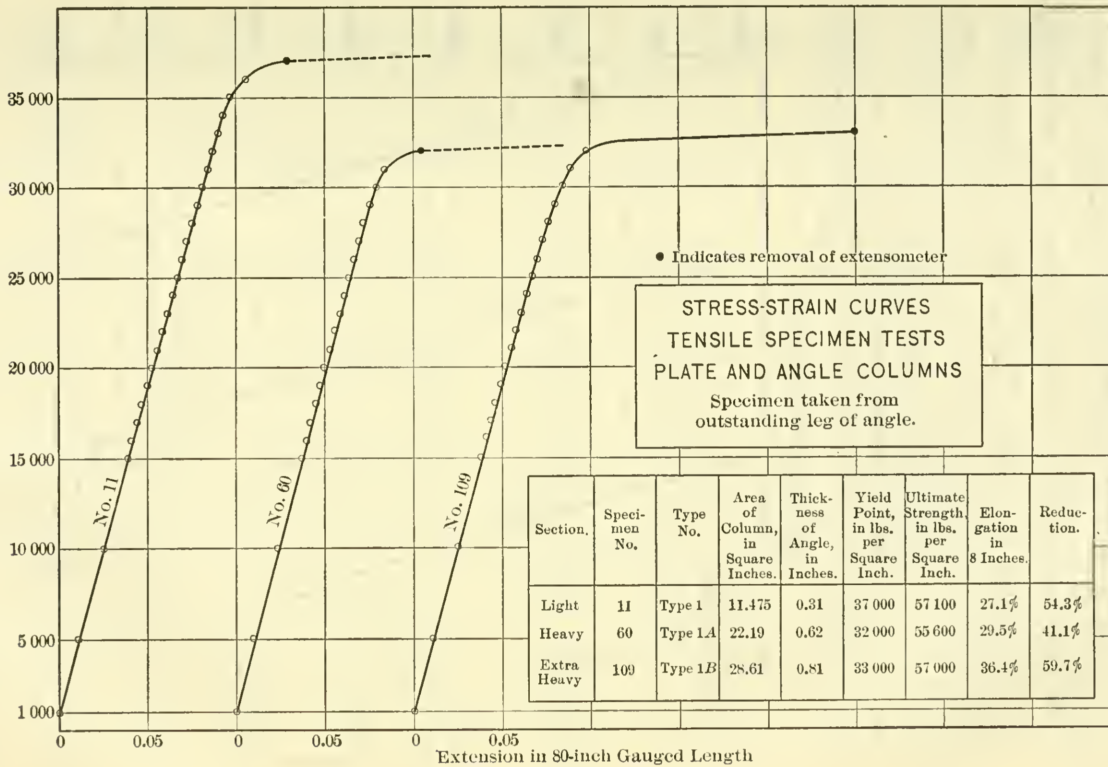
The results of some of these tests made by the Bureau are given in Figs. 2 and 3, which show stress-strain curves for six specimen tensile tests. Three of these curves, Fig. 2, are from specimens cut from the webs of three Bethlehem columns, of different thicknesses, while the other three, Fig. 3, are from specimens cut from the 5-in. outstanding legs of the angles of three plate and angle columns of different thicknesses.



Section.	Specimen No.	Column Test No.	Area of Column, in Square Inches.	Thickness of Web, in Inches.	Yield Point, in Pounds per Square Inch.	Ultimate Strength, in Pounds per Square Inch	Elongation.	Reduction.
Light	19 *BXC*	114	9.17	0.32	38 000	59 000	30.1% in 8 in.	50.4%
Heavy	15 *CXC*	106	18.27	0.55	33 000	57 500	27.8% in 8 in.	54.2%
Extra Heavy	24 *BXC*	183	26.64	0.78	26 000	56 500	39% in 2 in.	59%

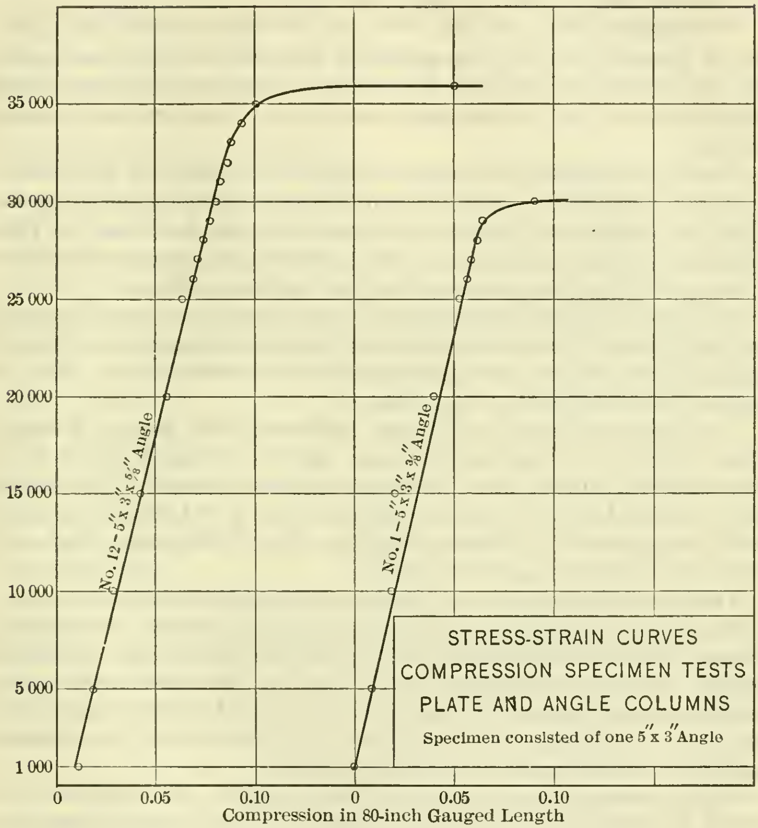
STRESS-STRAIN CURVES
TENSILE SPECIMEN TESTS
8" BETHLEHEM COLUMNS
Specimen taken from Web.

FIG. 2.



Section.	Specimen No.	Type No.	Area of Column, in Square Inches.	Thickness of Angle, in Inches.	Yield Point, in lbs. per Square Inch.	Ultimate Strength, in lbs. per Square Inch.	Elongation in 8 Inches.	Reduction.
Light	11	Type 1	11.475	0.31	37 000	57 100	27.1%	54.3%
Heavy	60	Type 1*A*	22.19	0.62	32 000	55 600	29.5%	41.1%
Extra Heavy	109	Type 1*B*	28.61	0.81	33 000	57 000	36.4%	59.7%

FIG. 3.



Section.	Specimen No.	Column Test No.	Nominal Area of Angle, in Square Inches.	$\frac{l}{r}$	Yield Point, in Pounds per Square Inch
Light	12	85	2.41	12.7	35 000
Heavy	1	99	4.61	12.7	29 500

FIG. 4.

Specimens cut from the flanges of the Bethlehem columns or from the plate of the plate and angle columns might possibly show somewhat different values, and your Committee realizes that it cannot draw conclusions from so small a number of tests.

Nevertheless, it appears that these specimen tests indicate the difference in strength between thin and thick material. It would also seem that the strength of the full-size columns is determined by the yield point, as shown by the specimen tests, rather than by the ultimate strength.

Another illustration of the same relation is shown in Fig. 4, which gives the stress-strain diagrams for specimen compression tests on 5 by 3-in. angles, used in plate and angle columns for Type 1. This same difference in yield point in the specimen test prognosticates the difference in the ultimate strength of the full-size columns.

On account of the close relation which appears to exist between the yield points of the metal and the ultimate strengths of columns, it would seem that one of the first questions to settle is what shall be taken as the yield point of the metal.

The American Society for Testing Materials, at its Annual Meeting, June, 1916, held a "topical discussion on the relation between yield point and proportional limit in various grades of steel". Discussions were submitted by Mr. Jas. E. Howard, Mr. T. D. Lynch, Messrs. H. F. Moore and F. B. Seeley, and Dr. G. R. Olshausen, Engineer-Physicist of the Bureau of Standards.

Your Committee has given careful consideration to this discussion, to find if it is possible to determine some point which, for practical purposes, may be easily located, clearly defined, and at the same time represent the limit where the metal ceases to have structural value. Modifications of some of the methods suggested have been discussed, and your Committee hopes that the data now being accumulated may assist in determining a practical solution.

Having agreed upon a method of determining what shall be considered a deformation point in specimen tests, the next question to be decided is whether the same method may be applied to the determination of the yield point in columns, or, if not, how this point shall be located. This opens up a field of inquiry which is comparatively unexplored.

In the Progress Report made by your Committee in 1910, a summary diagram* gave the results of all the major tests which had been published to that date. This summary was based on the ultimate strengths of the columns, for it will be recalled that earlier experimenters gave little attention to the question of yield point or elastic limit. It will be seen from this report, that the curves of ultimate

* *Transactions*, Am. Soc. C. E., Vol. LXVI, p. 426.

failure indicate very high values for short columns with slenderness ratio below $\frac{l}{r} = 30$. Now, the abstract of tests on columns of Type 1, slenderness ratio $\frac{l}{r} = 20$, Table 1, shows correspondingly high ultimate values, but when we consider the stress-strain curves, Fig. 1, it will be seen that the rate of compression of the column after the load has passed the yield point is such that the column has ceased to have structural value above this point.

A study of many stress-strain curves of the full-size column tests shows that comparatively low stresses produce initial sets, and these observations raise the same questions regarding proportional limit, elastic limit, and yield point which have been brought out by the specimen tests. Most of the tests in the Committee's programme have been made by successive run-ups of 5 000, 10 000, 15 000, 20 000 lb., and so on, up to the failure point. When the initial sets have been removed by such successive sequence of loadings, the curves, for the loads applied thereafter, show that the columns at stresses below the yield point act in true proportionality.

If this is the case, how shall we determine the elastic limit, or yield point? It would seem necessary to select some arbitrary deformation point, which could be used as a criterion of the strength of the column, and above which the column might be considered to have no further structural value.

It will be seen from the above that even with the records of the tests at hand, there are many things yet to be determined before your Committee can write a column formula. The questions of deformation point and ultimate strength above mentioned are important factors. Another question, even after determining the point above which the columns shall be considered to have no further structural value, is that of safe working values, and numerous factors must be considered in this connection. It will be recalled that the shapes for the column tests were chosen "with the intention, as far as practicable, of eliminating all variables except that of form". The influence of lattice bars, tie-plates and end connections has not entered into this programme, so that a third problem for your Committee is the study of effect of details.

Your Committee hopes to formulate its recommendations for designing columns during the coming year, and does not consider that its duty requires it to continue the investigations until the subject is exhausted, as that would necessitate an unlimited time.

Your Committee desires again to express its appreciation of the cordial co-operation and assistance which it has received from S. W. Stratton, Director, and G. R. Olshausen, Engineer-Physicist, of the Bureau of Standards.

In view of the foregoing statements, your Committee presents this report of progress.

For the Committee:
George H. Pegram,
Chairman.
Lewis D. Rights,
Secretary.

Committee:
Jas. H. Edwards,
C. W. Hudson,
Chas. F. Loweth,
Ralph Modjeski,
Frank C. Osborn,
George H. Pegram,
Lewis D. Rights,
George F. Swain,
Emil Swensson,
J. R. Worcester.

November 17th, 1916.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

FINAL REPORT
OF THE SPECIAL COMMITTEE
ON CONCRETE AND REINFORCED CONCRETE*

To the President and Members of the
American Society of Civil Engineers:

Gentlemen.—Your Special Committee on Concrete and Reinforced Concrete herewith presents, as its Final Report, the result of the joint efforts of its own members and of the representatives of other Societies appointed for the same purpose.

Respectfully submitted,

Joseph R. Worcester,
Chairman,
Richard L. Humphrey,
Secretary,
J. E. Greiner,
W. K. Hatt,
Olaf Hoff,
Robert W. Lesley,
Emil Swensson,
Arthur N. Talbot.

November 17th, 1916.

* To be presented to the Annual Meeting, January 17th, 1917.

FINAL REPORT
OF THE
JOINT COMMITTEE ON CONCRETE
AND REINFORCED CONCRETE

PRELIMINARY DRAFT PREPARED AND SUBMITTED BY THE SECRETARY, OCTOBER 27TH, 1908.

AMENDED AND ADOPTED BY LETTER-BALLOT OF THE COMMITTEE, DECEMBER 20TH, 1908.

REVISED AND BROUGHT UP TO DATE, NOVEMBER 20TH, 1912.

FINAL REPORT ADOPTED BY THE COMMITTEE, JULY 1ST, 1916.

AFFILIATED COMMITTEES

OF THE

American Society of Civil Engineers,
American Society for Testing Materials,
American Railway Engineering Association,
Portland Cement Association,
American Concrete Institute.

JULY 1ST, 1916.

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CHAPTER I.

Introduction.

The Joint Committee on Concrete and Reinforced Concrete was formed by the union of Special Committees appointed in 1903 and 1904 by the American Society of Civil Engineers, the American Society for Testing Materials, the American Railway Engineering and Maintenance of Way Association (now the American Railway Engineering Association), and the Association of American Portland Cement Manufacturers (now the Portland Cement Association). In 1915 there was added a Special Committee appointed by the American Concrete Institute at the invitation of the Joint Committee.

The present organization and membership of the Joint Committee is as follows:

Officers.

Chairman—Joseph R. Worcester.
Vice-Chairman—Emil Swensson.
Secretary—Richard L. Humphrey.

Members.

American Society of Civil Engineers.

John E. Greiner, Consulting Engineer, Baltimore, Md.

William K. Hatt, Professor of Civil Engineering, Purdue University, Lafayette, Ind.

Olaf Hoff, Consulting Engineer, 149 Broadway, New York, N. Y.

Richard L. Humphrey, Consulting Engineer, 805 Harrison Building, Philadelphia, Pa.

Robert W. Lesley, Past-President, Association of American Portland Cement Manufacturers, Pennsylvania Building, Philadelphia, Pa.

Emil Swensson, Consulting Engineer, 925 Frick Building, Pittsburgh, Pa.

Arthur N. Talbot, Professor of Municipal and Sanitary Engineering, University of Illinois, Urbana, Ill.

Joseph R. Worcester, Consulting Engineer, 79 Milk Street, Boston, Mass.

American Society for Testing Materials.

William B. Fuller, Consulting Engineer, 150 Nassau Street, New York, N. Y.

Edward E. Hughes, General Manager, Franklin Steel Works, Franklin, Pa.

Richard L. Humphrey, Consulting Engineer, 805 Harrison Building, Philadelphia, Pa.

ALBERT L. JOHNSON, First Vice-President and General Manager, Corrugated Bar Company, Mutual Life Building, Buffalo, N. Y.

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SANFORD E. THOMPSON, Consulting Engineer, 136 Federal Street, Boston, Mass.

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SAMUEL TOBIAS WAGNER, Chief Engineer, Philadelphia and Reading Railway Company, Reading Terminal, Philadelphia, Pa.

GEORGE S. WEBSTER, Director, Wharves, Docks, and Ferries, Bourse Building, Philadelphia, Pa.

AMERICAN RAILWAY ENGINEERING ASSOCIATION.

H. A. CASSIL, Division Engineer, Baltimore and Ohio Railway Company, New Castle, Pa.

FREDERICK E. SCHALL, Bridge Engineer, Lehigh Valley Railway Company, South Bethlehem, Pa.

FREDERICK P. SISSON, Assistant Engineer, Grand Trunk Railway, Detroit, Mich.

JOSEPH J. YATES, Bridge Engineer, Central Railroad of New Jersey, 143 Liberty Street, New York, N. Y.

PORTLAND CEMENT ASSOCIATION.

NORMAN D. FRASER, President, Chicago Portland Cement Company, 30 North La Salle Street, Chicago, Ill.

ROBERT E. GRIFFITH, Vice-President, Giant Portland Cement Company, Pennsylvania Building, Philadelphia, Pa.

SPENCER B. NEWBERRY, President, Sandusky Portland Cement Company, Engineers' Building, Cleveland, Ohio.

AMERICAN CONCRETE INSTITUTE.

EDWARD GODFREY, Structural Engineer, Robert W. Hunt & Co., Monongahela Building, Pittsburgh, Pa.

EGBERT J. MOORE, Chief Engineer, Turner Construction Company, 11 Broadway, New York, N. Y.

LEONARD C. WASON, President, Aberthaw Construction Company, 27 School Street, Boston, Mass.

Progress reports by the Joint Committee were presented to the parent societies in 1909 and 1912. The report presented in 1912 has been printed by the American Society of Civil Engineers, the American Society for Testing Materials, and the American Railway Engineering Association, and reference to that report may be made for details regarding the earlier work of the Joint Committee, a historical sketch of the introduction of concrete and reinforced concrete, and a bibliography of authorities upon which the report was based.

The Committee has been much gratified at the reception accorded its 1912 report, and realizes the responsibility which rests upon it because of the very extensive adoption of its recommendations in current practice in this country. The members of the Committee are well aware of the incompleteness of that report, and even now they are unable to pass judgment upon some matters not dealt with in the present report.

Since 1912 the Committee has continued its study of the subject, has followed the working out of its recommendations in actual construction, has weighed arguments and criticisms which have come to its attention, and has considered new experimental data. While the Committee sees no reason for making any fundamental changes, the recommendations of its previous report have been revised to some extent, and considerable new material has been added upon subjects not previously touched. There are some subjects upon which experimentation is still in progress, and the art of concrete and reinforced concrete will be advancing for many years to come.

While this report deals with every kind of stress to which concrete is subjected, and includes all ordinary conditions of proportioning and handling, it does not go into all types of construction nor all the applications to which concrete and reinforced concrete may be put. The report is not a specification, but may be used as a basis for specifications. In their use, concrete and reinforced concrete involve the exercise of good judgment to a greater degree than do any other building materials. Rules cannot produce or supersede judgment; on the contrary, judgment should control the interpretation and application of rules.

The Committee has not attempted in every case to present rigidly scientific methods of analysis in dealing with stresses, but has aimed to furnish rules which will lead to safe results sufficiently close for ordinary design.

The Committee presumes that the application of the recommendations in this report to the design of any structure will be made only by persons having an adequate knowledge of the principles of structural design. Only persons with such knowledge and experience should be called upon to design reinforced concrete structures.

The Joint Committee has reached the conclusion that, with this effort to express the present state of the art, it would be desirable for it to withdraw from the field. This action has been taken in the hope that a work similar to that which the Committee has attempted to perform will again be undertaken, within a reasonable term of years, in order that there may be some authoritative body to consider and pass upon newly acquired knowledge and information gleaned from experience. The Committee feels certain, however, that it would be for the better interest of the profession to entrust this work to other hands rather than to continue the present organization with this object in view.

CHAPTER II.

Adaptability of Concrete and Reinforced Concrete.

The adaptability of concrete and reinforced concrete for engineering structures or parts thereof, is so well established that they are recognized materials of construction. When properly used, they have proved satisfactory for those purposes for which their qualities make them particularly suitable.

1. USES.

Plain concrete is well adapted for structures in which the principal stresses are compressive, such as: foundations, dams, retaining and other walls, tunnels, piers, abutments, and, in many cases, arches.

By the use of metal reinforcement to resist the principal tensile stresses, concrete becomes available for general use in various structures and structural forms. This combination of concrete and metal is particularly advantageous in structural members subject to both compression and tension, and in columns where, although the main stresses are compressive, there is also cross-bending.

Metal reinforcement may also be used to advantage to distribute and minimize cracks due to shrinkage and temperature changes.

2. PRECAUTIONS.

Failures of reinforced concrete structures have been due usually to some one or more of the following causes:

Defective design, poor material, faulty execution, or premature removal of forms.

To prevent failures or otherwise unsatisfactory results, the following precautions should be taken:

The computations and assumptions on which the design is based should be in accordance with the established principles of mechanics. The unit stresses and details of the design should conform to ac-

cepted good practice. Materials used for the concrete as well as for the reinforcement should be carefully inspected and tested, special attention being given to the testing of the sand, as poor sand has proved a frequent cause of failure. The measuring and combining of the materials which go to make up the concrete, and the placing of the concrete in the forms, should be under the supervision of experienced men. The metal for reinforcement should be of a quality conforming to standard specifications. Care should be taken to obtain good bond between different fills of concrete, to prevent concrete from freezing before the cement has set, to have the materials thoroughly mixed, to avoid too wet or too dry a consistency, and to have the forms cleaned before concrete is placed.

The computations should include all details; even minor details may be of the utmost importance. The design should show clearly the size and position of the reinforcement, and should provide for proper connection between the component parts so that they cannot be displaced. As the connections between reinforced concrete members are frequently a source of weakness, the design should include a detailed study of such connections.

The concrete should be rigidly supported until it has developed sufficient strength to carry imposed loads. The most careful and experienced inspection is necessary to determine when the concrete has set sufficiently for it to be safe to remove forms. Frozen concrete frequently has been mistaken for properly set concrete.

3. DESIGN AND SUPERVISION.

The execution of the work should not be separated from the design, as intelligent supervision and successful execution can be expected only when both functions are combined. It is desirable, therefore, that the engineer who prepares the design and specifications should have supervision of the execution of the work.

The Committee recommends the following practice for the purpose of fixing the responsibility and providing for adequate supervision during construction.

(*a*) Before work is commenced, complete plans and specifications should be prepared, giving the dead and live loads, wind and impact, if any, and working stresses, showing the general arrangement and all details. The plans should show the size, length, location of points of bending, and exact position of all reinforcement, including stirrups, ties, hooping, and splicing.

(*b*) The specifications should state the qualities of the materials and the proportions in which they are to be used.

(*c*) The strength which the concrete is expected to attain after a definite period should be stated in the specifications.

(*d*) Inspection during construction should be made by competent inspectors selected by and under the supervision of the engineer, and should cover the following:

1. Materials.
2. Construction and erection of the forms and supports.
3. Sizes, shapes, arrangement, position, and fastening of the reinforcement.
4. Proportioning, mixing, consistency, and placing of the concrete.
5. Strength of the concrete by tests of standard test pieces made on the work.
6. Whether the concrete is sufficiently hardened before the forms and supports are removed.
7. Protection from injury of all parts of the structure.
8. Comparison of dimensions of all parts of the finished structure with the plans.

(*e*) Load tests on portions of the finished structure should be made where there is reasonable suspicion that the work has not been properly performed, or that, through influences of some kind, the strength has been impaired, or where there is any doubt as to the sufficiency of the design. The loading should be carried to such a point that the calculated stresses under such loading shall be one and three-quarters times the allowed working stresses, and such loads should cause no injurious permanent deformations. Load tests should not be made before the concrete has been in place 60 days.

4. DESTRUCTIVE AGENCIES.

(*a*) *Corrosion of Metal Reinforcement.*—Tests and experience indicate that steel sufficiently embedded in good concrete is well protected against corrosion, no matter whether located above or below water level. It is recommended that such protection be not less than 1 in. in thickness. If the concrete is porous so as to be readily permeable by water, as when the concrete is laid with a very dry consistency, the metal may corrode on account of the presence of moisture and air.

(*b*) *Electrolysis.*—The experimental data available on this subject seem to show that while reinforced concrete structures may, under certain conditions, be injured by the flow of electric current in either direction between the reinforcing material and the concrete, such injury is generally to be expected only where voltages are considerably higher than those which usually occur in concrete structures in practice. If the iron be positive, trouble may manifest itself by corrosion of the iron accompanied by cracking of the concrete, and, if the iron be negative, there may be a softening of the concrete near the surface of the iron, resulting in a destruction of the bond. The former, or anode effect, decreases much more rapidly than the voltage, and almost

if not quite disappears at voltages that are most likely to be encountered in practice. The cathode effect, on the other hand, takes place even for very low voltages, and is therefore more important from a practical standpoint than that of the anode.

Structures containing salt or calcium chloride, even in very small quantities, are very much more susceptible to the effects of electric currents than normal concrete, the anode effect progressing much more rapidly in the presence of chlorine, and the cathode effect being greatly increased by the presence of an alkali metal.

There is great weight of evidence to show that normal reinforced concrete structures free from salt are in very little danger under most practical conditions, while non-reinforced concrete structures are practically immune from electrolysis troubles.

(*c*) *Sea Water.*—The data available concerning the effect of sea water on concrete or reinforced concrete are limited and inconclusive. Sea walls out of the range of frost action have been standing for many years without apparent injury. In many places serious disintegration has taken place. This has occurred chiefly between low and high tide levels, and is due, evidently, in part to frost. Chemical action also appears to be indicated by the softening of the mortar. To effect the best resistance to sea water, the concrete must be proportioned, mixed, and placed so as to prevent the penetration of sea water into the mass or through the joints. The aggregates should be carefully selected, graded, and proportioned with the cement so as to secure the maximum possible density; the concrete should be thoroughly mixed; the joints between old and new work should be made water-tight; and the concrete should be kept from exposure to sea water until it is thoroughly hard and impervious.

(*d*) *Acids.*—Dense concrete thoroughly hardened is affected appreciably only by acids which seriously injure other materials. Substances like manure, that contain acids, may injuriously affect green concrete, but do not affect concrete that is thoroughly hardened.

(*e*) *Oils.*—Concrete is unaffected by such mineral oils as petroleum and ordinary engine oils. Oils which contain fatty acids produce injurious effects, forming compounds with the lime which may result in a disintegration of the concrete in contact with them.

(*f*) *Alkalies.*—The action of alkalies on concrete is problematical. In the reclamation of arid land, where the soil is heavily charged with alkaline salts, it has been found that concrete, stone, brick, iron, and other materials are injured under certain conditions. It would seem that at the level of the ground-water in an extremely dry atmosphere such structures are disintegrated, through the rapid crystallization of the alkaline salts, resulting from the alternate wetting and drying of the surface. Such destructive action can be prevented by the use of a protective coating, and is minimized by securing a dense concrete.

CHAPTER III.

Materials.

The quality of all the materials is of paramount importance. The cement and also the aggregates should be subject to definite requirements and tests.

1. cement.

There are available for construction purposes Portland, Natural, and Puzzolan or Slag cements.

(*a*) *Portland Cement* is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion, an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

It has a definite chemical composition varying within comparatively narrow limits.

Portland cement only should be used in reinforced concrete construction or in any construction that will be subject to shocks, vibrations, or stresses other than direct compression.

(*b*) *Natural Cement* is the finely pulverized product resulting from the calcination of an argillaceous limestone at a temperature only sufficient to drive off the carbonic acid gas.

Although the limestone must have a certain composition, this composition may vary within much wider limits than in the case of Portland cement. Natural cement does not develop its strength as quickly nor is it as uniform in composition as Portland cement.

Natural cement may be used in massive masonry where weight rather than strength is the essential feature.

Where economy is the governing factor, a comparison may be made between the use of natural cement and a leaner mixture of Portland cement that will develop the same strength.

(*c*) *Puzzolan or Slag Cement* is the product resulting from finely pulverizing a mechanical mixture of granulated basic blast-furnace slag and hydrated lime.

Puzzolan cement is not nearly as strong, uniform, or reliable as Portland or natural cement, is not used extensively, and never in important work; it should be used only for unimportant foundation work underground where it is not exposed to air or running water.

(*d*) *Specifications.*—The cement should meet the requirements of the specifications and methods of tests for Portland cement, which are the result of the joint labors of Special Committees of the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, and other affiliated organizations, and the United States Government.

2. AGGREGATES.

Extreme care should be exercised in selecting the aggregates for mortar and concrete, and careful tests made of the materials for the purpose of determining the quality and grading necessary to secure maximum density[1] or a minimum percentage of voids. Bank gravel should be separated by screening into fine and coarse aggregates and then used in the proportions to be determined by density tests.

(*a*) *Fine Aggregate* should consist of sand, or the screenings of gravel or crushed stone, graded from fine to coarse, and passing when dry a screen having ¼-in. diameter holes;[2] it preferably should be of siliceous material, and not more than 30% by weight, should pass a sieve having 50 meshes per lin. in.; it should be clean, and free from soft particles, lumps of clay, vegetable loam or other organic matter.

Fine aggregate should always be tested for strength. It should be of such quality that mortar composed of one part Portland cement and three parts fine aggregate by weight when made into briquettes, prisms or cylinders will show a tensile or compressive strength, at an age of not less than 7 days, at least equal to the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand.[3] If the aggregate be of poorer quality, the proportion of cement should be increased to secure the desired strength. If the strength developed by the aggregate in the 1:3 mortar is less than 70% of the strength of the Ottawa-sand mortar, the material should be rejected. In testing aggregates care should be exercised to avoid the removal of any coating on the grains, which may affect the strength; bank sands should not be dried before being made into mortar, but should contain natural moisture. The percentage of moisture may be determined upon a separate sample for correcting weight. From 10 to 40% more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency.

(*b*) *Coarse Aggregate* should consist of gravel or crushed stone which is retained on a screen having ¼-in. diameter holes, and should be graded from the smallest to the largest particles; it should be clean, hard, durable, and free from all deleterious matter. Aggregates containing dust and soft, flat, or elongated particles, should be excluded. The Committee does not feel warranted in recommending the use of blast-furnace slag as an aggregate, in the absence of adequate data as to its value, especially in reinforced concrete construction. No

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[1] A convenient coefficient of density is the ratio of the sum of the volumes of solid particles contained in a unit volume to the total unit volume.

[2] If the dividing size between the fine and coarse aggregate is less or greater than ¼ in., allowance should be made in grading and proportioning.

[3] A natural sand obtained at Ottawa, Illinois, passing a screen having 20 meshes and retained on a screen having 30 meshes per linear inch; prepared and furnished by the Ottawa Silica Company, for 2 cents per pound f. o. b. cars, Ottawa, Illinois.

satisfactory specifications or methods of inspection have been developed that will control its uniformity and ensure the durability of the concrete in which it is used.

The aggregate must be small enough to produce with the mortar a homogeneous concrete of sluggish consistency which will pass readily between and easily surround the reinforcement and fill all parts of the forms. The maximum size of particles is variously determined for different types of construction from that which will pass a ½-in. ring to that which will pass a 1½-in. ring.

For concrete in large masses the size of the coarse aggregate may be increased, as a large aggregate produces a stronger concrete than a fine one; however, it should be noted that the danger of separation from the mortar becomes greater as the size of the coarse aggregate increases.

Cinder concrete should not be used for reinforced concrete structures, except in floor-slabs not exceeding 8-ft. span. It also may be used for fire protection purposes where not required to carry loads. The cinders used should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes.

3. WATER.

The water used in mixing concrete should be free from oil, acid, alkali, or organic matter.

4. METAL REINFORCEMENT.

The Committee recommends as a suitable material for reinforcement, steel of structural grade filling the requirements of the Specifications for Billet Steel Concrete Reinforcement Bars of the American Society for Testing Materials.

For reinforcing slabs, small beams, or minor details, or for reinforcing for shrinkage and temperature stresses, steel wire, expanded metal, or other reticulated steel may be used, with the unit stresses hereinafter recommended.

The reinforcement should be free from flaking, rust, scale, or coatings of any character which would tend to reduce or destroy the bond.

CHAPTER IV.

Mixing and Placing.

1. PROPORTIONS.

The materials should be carefully selected, of uniform quality, and proportioned with a view to securing as nearly as possible a maximum density, which is obtained by grading the aggregates so that the smaller particles fill the spaces between the larger, thus reducing the voids in the aggregate to the minimum.

(*a*) *Unit of Measure.*—The measurement of the fine and coarse aggregates should be by loose volume. The unit of measure should be a bag of cement, containing 94 lb. net, which should be considered the equivalent of 1 cu. ft.

(*b*) *Relation of Fine and Coarse Aggregates.*—The fine and coarse aggregates should be used in such proportions as will secure maximum density. These proportions should be carefully determined by density experiments, and the grading of the fine and coarse aggregates should be uniformly maintained, or the proportions changed, to meet the varying sizes.

(*c*) *Relation of Cement and Aggregates.*—For reinforced concrete construction, one part of cement to a total of six parts of fine and coarse aggregates measured separately should generally be used. For columns, richer mixtures are preferable. In massive masonry or rubble concrete, a mixture of 1: 9 or even 1: 12 may be used.

These proportions should be determined by the strength or other qualities required in the construction at the critical period of use. Experience and judgment based on observation and tests of similar conditions in similar localities are excellent guides as to the proper proportions for any particular case.

In important construction, advance tests should be made on concrete composed of the materials to be used in the work. These tests should be made by standardized methods, to obtain uniformity in mixing, proportioning, and storage, and in case the results do not conform to the requirements of the work, aggregates of a better quality or more cement should be used to obtain the desired quality of concrete.

2. MIXING.

The mixing of concrete should be thorough, and continue until the mass is uniform in color and homogeneous. As the maximum density and greatest strength of a given mixture depend largely on thorough and complete mixing, it is essential that this part of the work should receive special attention and care.

Inasmuch as it is difficult to determine, by visual inspection, whether the concrete is uniformly mixed, especially where aggregates having the color of cement are used, it is essential that the mixing should occupy a definite period of time. The minimum time will depend on whether the mixing is done by machine or hand.

(*a*) *Measuring Ingredients.*—Methods of measurement of the various ingredients should be used which will secure at all times separate and uniform measurements of cement, fine aggregate, coarse aggregate, and water.

(*b*) *Machine Mixing.*—The mixing should be done in a batch machine mixer of a type which will ensure the uniform distribution of

the materials throughout the mass, and should continue for the minimum time of $1\frac{1}{2}$ min. after all the ingredients are assembled in the mixer. For mixers of two or more cubic yards capacity, the minimum time of mixing should be 2 min. Since the strength of the concrete is dependent upon thorough mixing, a longer time than this minimum is preferable. It is desirable to have the mixer equipped with an attachment for automatically locking the discharging device so as to prevent the emptying of the mixer until all the materials have been mixed together for the minimum time required after they are assembled in the mixer. Means should be provided to prevent aggregates being added after the mixing has commenced. The mixer should also be equipped with water storage, and an automatic measuring device which can be locked is desirable. It is also desirable to equip the mixer with a device recording the revolutions of the drum. The number of revolutions should be so regulated as to give at the periphery of the drum a uniform speed; about 200 ft. per min. seems to be the best speed in the present state of the art.

(c) *Hand Mixing.*—Hand mixing should be done on a water-tight platform and especial precautions taken after the water has been added, to turn all the ingredients together at least six times, and until the mass is homogeneous in appearance and color.

(d) *Consistency.*—The materials should be mixed wet enough to produce a concrete of such a consistency as will flow sluggishly into the forms and about the metal reinforcement when used, and which, at the same time, can be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar. The quantity of water is of the greatest importance in securing concrete of maximum strength and density; too much water is as objectionable as too little.

(e) *Retempering.*—The remixing of mortar or concrete that has partly set should not be permitted.

3. PLACING CONCRETE.

(a) *Methods.*—Concrete after the completion of the mixing should be conveyed rapidly to the place of final deposit; under no circumstances should concrete be used that has partly set.

Concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients are in their proper place. Special care should be exercised to prevent the formation of laitance; where laitance has formed it should be removed, since it lacks strength, and prevents a proper bond in the concrete.

Before depositing concrete, the reinforcement should be carefully placed in accordance with the plans. It is essential that adequate

means be provided to hold it in its proper position until the concrete has been deposited and compacted; care should be taken that the forms are substantial and thoroughly wetted (except in freezing weather) or oiled, and that the space to be occupied by the concrete is free from débris. When the placing of concrete is suspended, all necessary grooves for joining future work should be made before the concrete has set.

When work is resumed, concrete previously placed should be roughened, cleansed of foreign material and laitance, thoroughly wetted and then slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

The surfaces of concrete exposed to premature drying should be kept covered and wet for a period of at least 7 days.

Where concrete is conveyed by spouting, the plant should be of such a size and design as to ensure a practically continuous stream in the spout. The angle of the spout with the horizontal should be such as to allow the concrete to flow without a separation of the ingredients; in general an angle of about 27° or one vertical to two horizontal is good practice. The spout should be thoroughly flushed with water before and after each run. The delivery from the spout should be as close as possible to the point of deposit. Where the discharge must be intermittent, a hopper should be provided at the bottom. Spouting through a vertical pipe is satisfactory when the flow is continuous; when it is unchecked and discontinuous it is highly objectionable, unless the flow is checked by baffle plates.

(*b*) *Freezing Weather.*—Concrete should not be mixed or deposited at a freezing temperature, unless special precautions are taken to prevent the use of materials covered with ice crystals or containing frost, and to prevent the concrete from freezing before it has set and sufficiently hardened.

As the coarse aggregate forms the greater portion of the concrete, it is particularly important that this material be warmed to well above the freezing point.

The enclosing of a structure and the warming of the space inside the enclosure is recommended, but the use of salt to lower the freezing point is not recommended.

(*c*) *Rubble Concrete.*—Where the concrete is to be deposited in massive work, its value may be improved and its cost materially reduced by the use of clean stones, saturated with water, thoroughly embedded in and entirely surrounded by concrete.

(*d*) *Under Water.*—In placing concrete under water, it is essential to maintain still water at the place of deposit. With careful inspection, the use of tremies, properly designed and operated, is a satisfactory method of placing concrete through water. The concrete should be mixed very wet (more so than is ordinarily permissible) so that it

will flow readily through the tremie and into place with practically a level surface.

The coarse aggregate should be smaller than ordinarily used, and never more than 1 in. in diameter. The use of gravel facilitates mixing and assists the flow. The mouth of the tremie should be buried in the concrete so that it is at all times entirely sealed and the surrounding water prevented from forcing itself into the tremie; the concrete will then discharge without coming in contact with the water. The tremie should be suspended so that it can be lowered quickly when it is necessary either to choke off or prevent too rapid flow; the lateral flow preferably should be not over 15 ft.

The flow should be continuous in order to produce a monolithic mass and to prevent the formation of laitance in the interior.

In case the flow is interrupted, it is important that all laitance be removed before proceeding with the work.

In large structures it may be necessary to divide the mass of concrete into several small compartments or units, to permit the continuous filling of each one. With proper care it is possible in this manner to obtain as good results under water as in the air.

A less desirable method is the use of the drop-bottom bucket. Where this method is used, the bottom of the bucket should be released when in contact with the surface of the place of deposit.

CHAPTER V.

Forms.

Forms should be substantial and unyielding, in order that the concrete may conform to the design, and be sufficiently tight to prevent the leakage of mortar.

It is vitally important to allow sufficient time for the proper hardening of the concrete, which should be determined by careful inspection before the forms are removed.

Many conditions affect the hardening of concrete, and the proper time for the removal of the forms should be determined by some competent and responsible person.

It may be stated in a general way that forms should remain in place longer for reinforced concrete than is required for plain or massive concrete, and longer for horizontal than is required for vertical members.

In general it may be considered that concrete has hardened sufficiently when it has a distinctive ring under the blow of a hammer, but this test is not reliable, if there is a possibility that the concrete is frozen.

CHAPTER VI.

Details of Construction.

1. joints.

(*a*) *In Concrete.*—It is desirable to cast an entire structure at one operation, but as this is not always possible, especially in large structures, it is necessary to stop the work at some convenient point. This should be selected so that the resulting joint may have the least possible effect on the strength of the structure. It is therefore recommended that the joint in columns be made flush with the lower side of the girders, or in flat slab construction at the bottom of the flare of the column head; that the joints in girders be at a point midway between supports, unless a beam intersects a girder at this point, in which case the joint should be offset a distance equal to twice the width of the beam; and that the joints in the members of a floor system should in general be made at or near the center of the span.

Joints in columns should be perpendicular to the axis, and in girders, beams, and floor-slabs, perpendicular to the plane of their surfaces. When it is necessary to provide for shear at right angles to the axis, it is permissible to incline the plane of the joint as much as 30° from the perpendicular. Joints in arch rings should be on planes as nearly radial as practicable.

Before placing the concrete on top of a freshly poured column a period of at least 2 hours should be allowed for the settlement and shrinkage.

Shrinkage and contraction joints may be necessary to concentrate cracks due to temperature in smooth even lines. The number of these joints which should be determined and provided for in the design will depend on the range of temperature to which the concrete will be subjected, and on the amount and position of the reinforcement. In massive work, such as retaining walls, abutments, etc., built without reinforcement, contraction joints should be provided, at intervals of from 25 to 50 ft. and with reinforcement from 50 to 80 ft.; the smaller the height and thickness, the closer the spacing. The joints should be tongued and grooved to maintain the alignment in case of unequal settlement. A groove may be formed in the surface as a finish to vertical joints.

Shrinkage and contraction joints should be lubricated by an application of petroleum oil or a similar material, to permit a free movement when the concrete expands or contracts.

The movement of the joint due to expansion and contraction may be facilitated by the insertion of a sheet of copper, zinc, or even tarred paper.

(*b*) *In Reinforcement.*—Wherever it is necessary to splice tension reinforcement the length of lap should be determined on the basis of

the safe bond stress, the stress in the bar and the shearing resistance of the concrete at the point of splice; or a connection should be made between the bars of sufficient strength to carry the stress. Splices at points of maximum stress in tension should be avoided. In columns, bars more than $\frac{3}{4}$ in. in diameter not subject to tension should have their ends properly squared and butted together in suitable sleeves; smaller bars may be lapped, as indicated for tension reinforcement. At foundations bearing plates should be provided for supporting the bars, or the bars may be carried into the footing a sufficient distance to transmit the stress in the steel to the concrete by means of the bearing and the bond resistance. In no case should reliance be placed upon the end bearing of bars on concrete.

2. SHRINKAGE AND TEMPERATURE CHANGES.

The stresses resulting from shrinkage due to hardening and contraction from temperature changes are important in monolithic construction, and unless cared for in the design will produce objectionable cracks; cracks cannot be entirely prevented, but the effects can be minimized.

Large cracks, produced by quick hardening or wide ranges of temperature, can be broken up to some extent into small cracks by placing reinforcement in the concrete; in long, continuous lengths of concrete, it is better to provide shrinkage joints at points in the structure where they will do little or no harm. Reinforcement is of assistance, and permits longer distances between shrinkage joints than when no reinforcement is used.

Provision for shrinkage should be made when small or thin masses are joined to larger or thicker masses; at such places the use of fillets similar to those used in metal castings, but proportionally larger, is recommended.

Shrinkage cracks are likely to occur at points where fresh concrete is joined to that which is set, and hence in placing the concrete, construction joints should be made, as described in Chapter VI, Section 1, or, if possible, at points where joints would naturally occur in dimension-stone masonry.

3. FIRE-PROOFING.

Concrete, because incombustible and of a low rate of heat conductivity, is highly efficient and admirably adapted for fire-proofing purposes. This has been demonstrated by experience and tests.

The dehydration of concrete probably begins at about 500° Fahr. and is completed at about 900° Fahr., but experience indicates that the volatilization of the water absorbs heat from the surrounding mass, which, together with the resistance of the air cells, tends to increase the heat resistance of the concrete, so that the process of dehy-

dration is very much retarded. The concrete that is actually affected by fire and remains in position affords protection to that beneath it.

The thickness of the protective coating should be governed by the intensity and duration of a possible fire and the rate of heat conductivity of the concrete. The question of the rate of heat conductivity of concrete is one which requires further study and investigation before a definite rate for different classes of concrete can be fully established. However, for ordinary conditions, it is recommended that the metal be protected by a minimum of 2 in. of concrete on girders and columns, 1½ in. on beams, and 1 in. on floor-slabs.

Where fire-proofing is required, and not otherwise provided in monolithic concrete columns, it is recommended that the concrete to a depth of 1½ in. be considered as protective covering, and not included in the effective section.

The corners of columns, girders, and beams should be beveled or rounded, as a sharp corner is more seriously affected by fire than a round one; experience shows that round columns are more fire resistive than square.

4. WATER-PROOFING.

Many expedients have been resorted to for rendering concrete impervious to water. Experience shows, however, that when mortar or concrete is proportioned to obtain the greatest practicable density and is mixed to the proper consistency (Chapter IV, Section 2 *d*), the resulting mortar or concrete is impervious under moderate pressure.

On the other hand, concrete of dry consistency is more or less pervious to water, and, though compounds of various kinds have been mixed with the concrete or applied as a wash to the surface, in an effort to offset this defect, these expedients have generally been disappointing, for the reason that many of these compounds have at best but temporary value, and in time lose their power of imparting impermeability to the concrete.

In the case of subways, long retaining walls and reservoirs, provided the concrete itself is impervious, cracks may be so reduced, by horizontal and vertical reinforcement properly proportioned and located, that they will be too minute to permit leakage, or will be closed by infiltration of silt.

Asphaltic or coal-tar preparations applied either as a mastic or as a coating on felt or cloth fabric, are used for water-proofing, and should be proof against injury by liquids or gases.

For retaining and similar walls in direct contact with the earth, the application of one or two coatings of hot coal-tar pitch, following a painting with a thin wash of coal tar dissolved in benzol, to the thoroughly dried surface of concrete is an efficient method of preventing the penetration of moisture from the earth.

5. SURFACE FINISH.

Concrete is a material of an individual type, and should be used without effort at imitation of other building materials. One of the important problems connected with its use is the character of the finish of exposed surfaces. The desired finish should be determined before the concrete is placed, and the work conducted so as to facilitate securing it. The natural surface of the concrete in most structures is unobjectionable, but in others the marks of the forms and the flat dead surface are displeasing, making some special treatment desirable. A treatment of the surface which removes the film of cement and brings the aggregates of the concrete into relief, either by scrubbing with brushes and water before it is hard, or by tooling it after it is hard, is frequently used to erase the form markings and break the monotonous appearance of the surface. Besides being more pleasing in immediate appearance, such a surface is less subject to discoloration and hair cracking than is a surface composed of the cement that segregates against the forms, or one that is made by applying a cement wash. The aggregates can also be exposed by washing with hydrochloric acid diluted with from 6 to 10 parts of water. The plastering of surfaces should be avoided, for even if carefully done, it is liable to peel off under the action of frost or temperature changes.

Various effects in texture and in color can be obtained when the surface is to be scrubbed or tooled, by using aggregates of the desired size and color. For a fine-grained texture a granolithic surface mixture can be made and placed against the face forms to a thickness of about 1 in. as the placing of the body of the concrete proceeds.

A smooth, even surface without form marks can be secured by the use of plastered forms, which, in structures having many duplications of members, can be used repeatedly; these are made in panels of expanded metal or wire mesh coated with plaster, and the joints made at edges, and closed with plaster of Paris.

CHAPTER VII.

Design.

1. MASSIVE CONCRETE.

In the design of massive or plain concrete, no account should be taken of the tensile strength of the material, and sections should usually be proportioned so as to avoid tensile stresses except in slight amounts to resist indirect stresses. This will generally be accomplished in the case of rectangular shapes if the line of pressure is kept within the middle third of the section, but in very large structures, such as high masonry dams, a more exact analysis may be required. Structures of massive concrete are able to resist unbalanced lateral

forces by reason of their weight; hence the element of weight rather than strength often determines the design. A leaner and relatively cheap concrete, therefore, will often be suitable for massive concrete structures.

It is desirable generally to provide joints at intervals to localize the effect of contraction (Chapter VI, Section 1).

Massive concrete is suitable for dams, retaining walls, and piers in which the ratio of length to least width is relatively small. Under ordinary conditions, this ratio should not exceed four. It is also suitable for arches of moderate span.

2. REINFORCED CONCRETE.

The use of metal reinforcement is particularly advantageous in members such as beams in which both tension and compression exist, and in columns where the principal stresses are compressive and where there also may be cross-bending. Therefore the theory of design here presented relates mainly to the analysis of beams and columns.

3. GENERAL ASSUMPTIONS.

(*a*) *Loads.*—The forces to be resisted are those due to:

1. *The dead load,* which includes the weight of the structure and fixed loads and forces.
2. *The live load,* or the loads and forces which are variable. The dynamic effect of the live load will often require consideration. Allowance for the latter is preferably made by a proportionate increase in either the live load or the live-load stresses. The working stresses hereinafter recommended are intended to apply to the equivalent static stresses thus determined.

   In the case of high buildings, the live load on columns may be reduced in accordance with the usual practice.

(*b*) *Lengths of Beams and Columns.*—The span length for beams and slabs simply supported should be taken as the distance from center to center of supports, but need not be taken to exceed the clear span plus the depth of beam or slab. For continuous or restrained beams built monolithically into supports, the span length may be taken as the clear distance between faces of supports. Brackets should not be considered as reducing the clear span in the sense here intended, except that when brackets which make an angle of 45° or more with the axis of a restrained beam are built monolithically with the beam, the span may be measured from the section where the combined depth of beam and bracket is at least one-third more than the depth of the beam. Maximum negative moments are to be considered as existing at the end of the span as here defined.

When the depth of a restrained beam is greater at its ends than at mid-span and the slope of the bottom of the beam at its ends makes an angle of not more than 15° with the direction of the axis of the beam at mid-span, the span length may be measured from face to face of supports.

The length of columns should be taken as the maximum unstayed length.

(*c*) *Stresses.*—The following assumptions are recommended as a basis for calculations:

1. Calculations will be made with reference to working stresses and safe loads, rather than with reference to ultimate strength and ultimate loads.
2. A plane section before bending remains plane after bending.
3. The modulus of elasticity of concrete in compression is constant within the usual limits of working stresses. The distribution of compressive stress in beams is therefore rectilinear.
4. In calculating the moment of resistance of beams, the tensile stresses in the concrete are neglected.
5. The adhesion between the concrete and the reinforcement is perfect. Under compressive stress the two materials are therefore stressed in proportion to their moduli of elasticity.
6. The ratio of the modulus of elasticity of steel to the modulus of elasticity of concrete is taken at 15 except as modified in Chapter VIII, Section 8.
7. Initial stress in the reinforcement due to contraction or expansion of the concrete is neglected.

It is recognized that some of the assumptions given herein are not entirely borne out by experimental data. They are given in the interest of simplicity and uniformity, and variations from exact conditions are taken into account in the selection of formulas and working stresses.

The deflection of a beam depends upon the strength and stiffness developed throughout its length. For calculating deflection, a value of 8 for the ratio of the moduli will give results corresponding approximately with the actual conditions.

4. T-BEAMS.

In beam and slab construction an effective bond should be provided at the junction of the beam and slab. When the principal slab reinforcement is parallel to the beam, transverse reinforcement should be used, extending over the beam and well into the slab.

The slab may be considered an integral part of the beam, when adequate bond and shearing resistance between slab and web of beam is provided, but its effective width shall be determined by the following rules:

(*a*) It shall not exceed one-fourth of the span length of the beam;

(*b*) Its overhanging width on either side of the web shall not exceed six times the thickness of the slab.

In the design of continuous T-beams, due consideration should be given to the compressive stress at the support.

Beams in which the T-form is used only for the purpose of providing additional compression area of concrete should preferably have a width of flange not more than three times the width of the stem and a thickness of flange not less than one-third of the depth of the beam. Both in this form and in the beam and slab form the web stresses and the limitations in placing and spacing the longitudinal reinforcement will probably be controlling factors in design.

5. FLOOR-SLABS SUPPORTED ALONG FOUR SIDES.

Floor-slabs having the supports extending along the four sides should be designed and reinforced as continuous over the supports. If the length of the slab exceeds one and one-half times its width, the entire load should be carried by transverse reinforcement.

For uniformly distributed loads on square slabs, one-half the live and dead load may be used in the calculations of moment to be resisted in each direction. For oblong slabs, the length of which is not greater than one and one-half times their width, the moment to be resisted by the transverse reinforcement may be found by using a proportion of the live and dead load equal to that given by the formula, $r = \frac{l}{b} - 0.5$, where l = length and b = breadth of slab. The longitudinal reinforcement should then be proportioned to carry the remainder of the load.

In placing reinforcement in such slabs account may well be taken of the fact that the bending moment is greater near the center of the slab than near the edges. For this purpose two-thirds of the previously calculated moments may be assumed as carried by the center half of the slab and one-third by the outside quarters.

Loads carried to beams by slabs which are reinforced in two directions will not be uniformly distributed to the supporting beams, and the distribution will depend on the relative stiffness of the slab and the supporting beams. The distribution which may be expected ordinarily is a variation of the load in the beam in accordance with

the ordinates of a parabola, having its vertex at the middle of the span. For any given design, the probable distribution should be ascertained and the moments in the beam calculated accordingly.

6. CONTINUOUS BEAMS AND SLABS.

When the beam or slab is continuous over its supports, reinforcement should be fully provided at points of negative moment, and the stresses in concrete recommended in Chapter VIII, Section 4, should not be exceeded. In computing the positive and negative moments in beams and slabs continuous over several supports, due to uniformly distributed loads, the following rules are recommended:

(*a*) For floor-slabs, the bending moments at center and at support should be taken at $\frac{wl^2}{12}$ for both dead and live loads, where w represents the load per linear unit and l the span length.

(*b*) For beams, the bending moment at center and at support for interior spans should be taken at $\frac{wl^2}{12}$ and for end spans it should be taken at $\frac{wl^2}{10}$ for center and interior support, for both dead and live loads.

(*c*) In the case of beams and slabs continuous for two spans only, with their ends restrained, the bending moment both at the central support and near the middle of the span should be taken as $\frac{wl^2}{10}$.

(*d*) At the ends of continuous beams, the amount of negative moment which will be developed in the beam will depend on the condition of restraint or fixedness, and this will depend on the form of construction used. In the ordinary cases a moment of $\frac{wl^2}{16}$ may be taken; for small beams running into heavy columns this should be increased, but not to exceed $\frac{wl^2}{12}$.

For spans of unusual length, or for spans of materially unequal length, more exact calculations should be made. Special consideration is also required in the case of concentrated loads.

Even if the center of the span is designed for a greater bending moment than is called for by (*a*) or (*b*), the negative moment at the support should not be taken as less than the values there given.

Where beams are reinforced on the compression side, the steel may be assumed to carry its proportion of stress in accordance with the ratio of moduli of elasticity, Chapter VIII, Section 8. Reinforcing bars for compression in beams should be straight and should be two diameters in the clear from the surface of the concrete. For the positive bending moment, such reinforcement should not exceed 1% of the area of the concrete. In the case of cantilever and continuous beams, tensile and compressive reinforcement over supports should extend sufficiently beyond the support and beyond the point of inflection to develop the requisite bond strength.

In construction made continuous over supports, it is important that ample foundations should be provided; for unequal settlements are liable to produce unsightly if not dangerous cracks. This effect is more likely to occur in low structures.

Girders, such as wall girders, which have beams framed into one side only, should be designed to resist torsional moment arising from the negative moment at the end of the beam.

7. BOND STRENGTH AND SPACING OF REINFORCEMENT.

Adequate bond strength should be provided. The formula hereinafter given for bond stresses in beams is for straight longitudinal bars. In beams in which a portion of the reinforcement is bent up near the end, the bond stress at places, in both the straight bars and the bent bars, will be considerably greater than for all the bars straight, and the stress at some point may be several times as much as that found by considering the stress to be uniformly distributed along the bar. In restrained and cantilever beams, full tensile stress exists in the reinforcing bars at the point of support, and the bars should be anchored in the support sufficiently to develop this stress.

In case of anchorage of bars, an additional length of bar should be provided beyond that found on the assumption of uniform bond stress, for the reason that before the bond resistance at the end of the bar can be developed the bar may have begun to slip at another point, and "running" resistance is less than the resistance before slip begins.

Where high bond resistance is required, the deformed bar is a suitable means of supplying the necessary strength. But it should be recognized that, even with a deformed bar, initial slip occurs at early loads, and that the ultimate loads obtained in the usual tests for bond resistance may be misleading. Adequate bond strength throughout the length of a bar is preferable to end anchorage, but, as an additional safeguard, such anchorage may properly be used in special cases. Anchorage furnished by short bends at a right angle is less effective than by hooks consisting of turns through 180 degrees.

The lateral spacing of parallel bars should be not less than three diameters from center to center, nor should the distance from the side of the beam to the center of the nearest bar be less than two diameters. The clear spacing between two layers of bars should be not less than 1 in. The use of more than two layers is not recommended, unless the layers are tied together by adequate metal connections, particularly at and near points where bars are bent up or bent down. Where more than one layer is used, at least all bars above the lower layer should be bent up and anchored beyond the edge of the support.

8. DIAGONAL TENSION AND SHEAR.

When a reinforced concrete beam is subjected to flexural action, diagonal tensile stresses are set up. A beam without web reinforcement will fail if these stresses exceed the tensile strength of the concrete. When web reinforcement, made up of stirrups or of diagonal bars secured to the longitudinal reinforcement, or of longitudinal reinforcing bars bent up at several points, is used, new conditions prevail, but, even in this case, at the beginning of loading the diagonal tension developed is taken principally by the concrete, the deformations which are developed in the concrete permitting but little stress to be taken by the web reinforcement. When the resistance of the concrete to the diagonal tension is overcome at any point in the depth of the beam, greater stress is at once set up in the web reinforcement.

For homogeneous beams, the analytical treatment of diagonal tension is not very complex—the diagonal tensile stress is a function of the horizontal and vertical shearing stresses and of the horizontal tensile stress at the point considered, and as the intensity of these three stresses varies from the neutral axis to the remotest fiber, the intensity of the diagonal tension will be different at different points in the section, and will change with different proportionate dimensions of length to depth of beam. For the composite structure of reinforced concrete beams, an analysis of the web stresses, and particularly of the diagonal tensile stresses, is very complex; and when the variations due to a change from no horizontal tensile stress in the concrete at remotest fiber to the presence of horizontal tensile stress at some point below the neutral axis are considered, the problem becomes more complex and indefinite. Under these circumstances, in designing, recourse is had to the use of the calculated vertical shearing stress, as a means of comparing or measuring the diagonal tensile stresses developed, it being understood that the vertical shearing stress is not the numerical equivalent of the diagonal tensile stress, and that there is not even a constant ratio between them. It is here recommended that the maximum vertical shearing stress in a section be used as the means of

comparison of the resistance to diagonal tensile stress developed in the concrete in beams not having web reinforcement.

Even after the concrete has reached its limit of resistance to diagonal tension, if the beam has web reinforcement, conditions of beam action will continue to prevail, at least through the compression area, and the web reinforcement will be called on to resist only a part of the web stresses. From experiments with beams it is concluded that it is safe practice to use only two-thirds of the external vertical shear in making calculations of the stresses that come on stirrups, diagonal web pieces, and bent-up bars, and it is here recommended for calculations in designing that two-thirds of the external vertical shear be taken as producing stresses in web reinforcement.

It is well established that vertical members attached to or looped about horizontal members, inclined members secured to horizontal members in such a way as to insure against slip, and the bending of a part of the longitudinal reinforcement at an angle, will increase the strength of a beam against failure by diagonal tension, and that a well-designed and well-distributed web reinforcement may, under the best conditions, increase the total vertical shear carried to a value as much as three times that obtained when the bars are all horizontal and no web reinforcement is used.

When web reinforcement comes into action as the principal tension web resistance, the bond stresses between the longitudinal bars and the concrete are not distributed as uniformly along the bars as they otherwise would be, but tend to be concentrated at and near stirrups, and at and near the points where bars are bent up. When stirrups are not rigidly attached to the longitudinal bars, and the proportioning of bars and stirrup spacing is such that local slip of bars occur at stirrups, the effectiveness of the stirrups is impaired, though the presence of stirrups still gives an element of toughness against diagonal tension failure.

Sufficient bond resistance between the concrete and the stirrups or diagonals must be provided in the compression area of the beam.

The longitudinal spacing of vertical stirrups should not exceed one-half the depth of beam, and that of inclined members should not exceed three-fourths of the depth of beam.

Bending of longitudinal reinforcing bars at an angle across the web of the beam may be considered as adding to diagonal tension resistance for a horizontal distance from the point of bending equal to three-fourths of the depth of beam. Where the bending is made at two or more points, the distance between points of bending should not exceed three-fourths of the depth of the beam. In the case of a restrained beam, the effect of bending up a bar at the bottom of the beam in resisting diagonal tension may not be taken as extending

beyond a section at the point of inflection, and the effect of bending down a bar in the region of negative moment may be taken as extending from the point of bending down of bar nearest the support to a section not more than three-fourths of the depth of beam beyond the point of bending down of bar farthest from the support, but not beyond the point of inflection. In case stirrups are used in the beam away from the region in which the bent bars are considered effective, a stirrup should be placed not farther than a distance equal to one-fourth the depth of beam from the limiting sections defined above. In case the web resistance required through the region of bent bars is greater than that furnished by the bent bars, sufficient additional web reinforcement in the form of stirrups or attached diagonals should be provided. The higher resistance to diagonal tension stresses given by unit frames having the stirrups and bent-up bars securely connected together both longitudinally and laterally is worthy of recognition. It is necessary that a limit be placed on the amount of shear which may be allowed in a beam; for when web reinforcement sufficiently efficient to give very high web resistance is used, at the higher stresses the concrete in the beam becomes checked and cracked in such a way as to endanger its durability as well as its strength.

The section to be taken as the critical section in the calculation of shearing stresses will generally be the one having the maximum vertical shear, though experiments show that the section at which diagonal tension failures occur is not just at a support, even though the shear at the latter point be much greater.

In the case of restrained beams, the first stirrup or the point of bending down of bar should be placed not farther than one-half of the depth of beam away from the face of the support.

It is important that adequate bond strength or anchorage be provided to develop fully the assumed strength of all web reinforcement.

Low bond stresses in the longitudinal bars are helpful in giving resistance against diagonal tension failures, and anchorage of longitudinal bars at the ends of the beams or in the supports is advantageous.

It should be noted that it is on the tension side of a beam that diagonal tension develops in a critical way, and that proper connection should always be made between stirrups or other web reinforcement and the longitudinal tension reinforcement, whether the latter is on the lower side of the beam or on its upper side. Where negative moment exists, as is the case near the supports in a continuous beam, web reinforcement, to be effective, must be looped over or wrapped around, or be connected with, the longitudinal tension reinforcing bars at the top of the beam in the same way as is necessary at the bottom of the beam at sections where the bending moment is positive.

Inasmuch as the smaller the longitudinal deformations in the

horizontal reinforcement are, the less the tendency for the formation of diagonal cracks, a beam will be strengthened against diagonal tension failure by so arranging and proportioning the horizontal reinforcement that the unit stresses at points of large shear shall be relatively low.

It does not seem feasible to make a complete analysis of the action of web reinforcement, and more or less empirical methods of calculation are therefore employed. Limiting values of working stresses for different types of web reinforcement are given in Chapter VIII, Section 5. The conditions apply to cases commonly met in design. It is assumed that adequate bond resistance or anchorage of all web reinforcement will be provided.

When a flat slab rests on a column, or a column bears on a footing, the vertical shearing stresses in the slab or footing immediately adjacent to the column are termed punching shearing stresses. The element of diagonal tension, being a function of the bending moment as well as of shear, may be small in such cases, or may be otherwise provided for. For this reason the permissible limit of stress for punching shear may be higher than the allowable limit when the shearing stress is used as a means of comparing diagonal tensile stress. The working values recommended are given in Chapter VIII, Section 5.

9. COLUMNS.

By columns are meant compression members of which the ratio of unsupported length to least width exceeds about four, and which are provided with reinforcement of one of the forms hereafter described.

It is recommended that the ratio of unsupported length of column to its least width be limited to 15.

The effective area of hooped columns or columns reinforced with structural shapes shall be taken as the area within the circle enclosing the spiral or the polygon enclosing the structural shapes.

Columns may be reinforced by longitudinal bars; by bands, hoops, or spirals, together with longitudinal bars; or by structural forms which are sufficiently rigid to have value in themselves as columns. The general effect of closely spaced hooping is to greatly increase the toughness of the column and to add to its ultimate strength, but hooping has little effect on its behavior within the limit of elasticity. It thus renders the concrete a safer and more reliable material, and should permit the use of a somewhat higher working stress. The beneficial effects of toughening are adequately provided by a moderate amount of hooping, a larger amount serving mainly to increase the ultimate strength and the deformation possible before ultimate failure.

Composite columns of structural steel and concrete, in which the steel forms a column by itself, should be designed with caution. To classify this type as a concrete column reinforced with structural

steel is hardly permissible, as the steel generally will take the greater part of the load. When this type of column is used, the concrete should not be relied upon to tie the steel units together nor to transmit stresses from one unit to another. The units should be adequately tied together by tie-plates or lattice bars, which, together with other details, such as splices, etc., should be designed in conformity with standard practice for structural steel. The concrete may exert a beneficial effect in restraining the steel from lateral deflection and also in increasing the carrying capacity of the column. The proportion of load to be carried by the concrete will depend on the form of the column and the method of construction. Generally, for high percentages of steel, the concrete will develop relatively low unit stresses, and caution should be used in placing dependence on the concrete.

The following recommendations are made for the relative working stresses in the concrete for the several types of columns:

(*a*) Columns with longitudinal reinforcement to the extent of not less than 1% and not more than 4%, and with lateral ties of not less than ¼ in. in diameter, 12 in. apart, nor more than 16 diameters of the longitudinal bar: the unit stress recommended for axial compression, on concrete piers having a length not more than four diameters, in Chapter VIII, Section 3.

(*b*) Columns reinforced with not less than 1% and not more than 4% of longitudinal bars and with circular hoops or spirals not less than 1% of the volume of the concrete and as hereinafter specified: a unit stress 55% higher than given for (*a*), provided the ratio of unsupported length of column to diameter of the hooped core is not more than 10.

The foregoing recommendations are based on the following conditions:

It is recommended that the minimum size of columns to which the working stresses may be applied be 12 in., out to out.

In all cases longitudinal reinforcement is assumed to carry its proportion of stress in accordance with Section 3 (*c*) 6 of this chapter. The hoops or bands are not to be counted on directly as adding to the strength of the column.

Longitudinal reinforcement bars should be maintained straight, and shall have sufficient lateral support to be securely held in place until the concrete has set.

Where hooping is used, the total amount of such reinforcement shall be not less than 1% of the volume of the column, enclosed. The clear spacing of such hooping shall be not greater than one-sixth the diameter of the enclosed column, and preferably not greater than one-

tenth, and in no case more than $2\frac{1}{2}$ in. Hooping is to be circular and the ends of bands must be united in such a way as to develop their full strength. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered. The strength of hooped columns depends very much upon the ratio of length to diameter of hooped core, and the strength due to hooping decreases rapidly as this ratio increases beyond five. The working stresses recommended are for hooped columns with a length of not more than ten diameters of the hooped core. The Committee has no recommendation to make for a formula for working stresses for columns longer than ten diameters.

Bending stresses due to eccentric loads, such as unequal spans of beams, and to lateral forces, must be provided for by increasing the section until the maximum stress does not exceed the values above specified. Where tension is possible in the longitudinal bars of the column, adequate connection between the ends of the bars must be provided to take this tension.

10. REINFORCING FOR SHRINKAGE AND TEMPERATURE STRESSES.

When areas of concrete too large to expand and contract freely as a whole are exposed to atmospheric conditions, the changes of form due to shrinkage and to action of temperature are such that cracks may occur in the mass unless precautions are taken to distribute the stresses so as to prevent the cracks altogether or to render them very small. The distance apart of the cracks, and consequently their size, will be directly proportional to the diameter of the reinforcement and to the tensile strength of the concrete, and inversely proportional to the percentage of reinforcement and also to its bond resistance per unit of surface area. To be most effective, therefore, reinforcement (in amount generally not less than one-third of 1% of the gross area) of a form which will develop a high bond resistance should be placed near the exposed surface and be well distributed. Where openings occur the area of cross-section of the reinforcement should not be reduced. The allowable size and spacing of cracks depends on various considerations, such as the necessity for water-tightness, the importance of appearance of the surface, and the atmospheric changes.

The tendency of concrete to shrink makes it necessary, except where expansion is provided for, to thoroughly connect the component parts of the frame of articulated structures, such as floor and wall members in buildings, by the use of suitable reinforcing material. The amount of reinforcement for such connection should bear some relation to the size of the members connected, larger and heavier members requiring stronger connections. The reinforcing bars should be extended beyond the critical section far enough, or should be sufficiently anchored to develop their full tensile strength.

11. FLAT SLAB.

The continuous flat slab reinforced in two or more directions and built monolithically with the supporting columns (without beams or girders) is a type of construction which is now extensively used and which has recognized advantages for certain types of structures as, for example, warehouses in which large, open floor space is desired. In its construction, there is excellent opportunity for inspecting the position of the reinforcement. The conditions attending depositing and placing of concrete are favorable to securing uniformity and soundness in the concrete. The recommendations in the following paragraphs relate to flat slabs extending over several rows of panels in each direction. Necessarily the treatment is more or less empirical. The coefficients and moments given relate to uniformly distributed loads.

(*a*) *Column Capital.*—It is usual in flat slab construction to enlarge the supporting columns at their top, thus forming column capitals. The size and shape of the column capital affect the strength of the structure in several ways. The moment of the external forces which the slab is called upon to resist is dependent upon the size of the capital; the section of the slab immediately above the upper periphery of the capital carries the highest amount of punching shear; and the bending moment developed in the column by an eccentric or unbalanced loading of the slab is greatest at the under surface of the slab. Generally, the horizontal section of the column capital should be round or square with rounded corners. In oblong panels the section may be oval or oblong, with dimensions proportional to the panel dimensions. For computation purposes, the diameter of the column capital will be considered to be measured where its vertical thickness is at least 1½ in., provided the slope of the capital below this point nowhere makes an angle with the vertical of more than 45 degrees. In case a cap is placed above the column capital, the part of this cap within a cone made by extending the lines of the column capital upward at the slope of 45° to the bottom of the slab or dropped panel may be considered as part of the column capital in determining the diameter for design purposes. Without attempting to limit the size of the column capital for special cases, it is recommended that the diameter of the column capital (or its dimension parallel to the edge of the panel) generally be made not less than one-fifth of the dimension of the panel from center to center of adjacent columns. A diameter equal to 0.225 of the panel length has been used quite widely and acceptably. For heavy loads or large panels, especial attention should be given to designing and reinforcing the column capital with respect to compressive stresses and bending moments. In the case of heavy loads or large panels, and where the conditions of the panel loading

or variations in panel length or other conditions cause high bending stresses in the column, and also for column capitals smaller than the size herein recommended, especial attention should be given to designing and reinforcing the column capital with respect to compression and to rigidity of connection to floor-slab.

(*b*) *Dropped Panel.*—In one type of construction the slab is thickened throughout an area surrounding the column capital. The square or oblong of thickened slab thus formed is called a dropped panel or a drop. The thickness and the width of the dropped panel may be governed by the amount of resisting moment to be provided (the compressive stress in the concrete being dependent upon both thickness and width), or its thickness may be governed by the resistance to shear required at the edge of the column capital and its width by the allowable compressive stresses and shearing stresses in the thinner portion of the slab adjacent to the dropped panel. Generally, however, it is recommended that the width of the dropped panel be at least four-tenths of the corresponding side of the panel as measured from center to center of columns, and that the offset in thickness be not more than five-tenths of the thickness of the slab outside the dropped panel.

(*c*) *Slab Thickness.*—In the design of a slab, the resistance to bending and to shearing forces will largely govern the thickness, and, in the case of large panels with light loads, resistance to deflection may be a controlling factor. The following formulas for minimum thicknesses are recommended as general rules of design when the diameter of the column capital is not less than one-fifth of the dimension of the panel from center to center of adjacent columns, the larger dimension being used in the case of oblong panels. For notation, let

t = total thickness of slab, in inches;
L = panel length, in feet;
w = sum of live load and dead load, in pounds per square foot.

Then, for a slab without dropped panels,

$$\text{minimum } t = 0.024\, L \sqrt{w} + 1\tfrac{1}{2}\,;$$

for a slab with dropped panels,

$$\text{minimum } t = 0.02\, L \sqrt{w} + 1\,;$$

for a dropped panel whose width is four-tenths of the panel length,

$$\text{minimum } t = 0.03\, L \sqrt{w} + 1\tfrac{1}{2}.$$

In no case should the slab thickness be made less than 6 in., nor should the thickness of a floor-slab be made less than one-thirty-second of the panel length, nor the thickness of a roof slab less than one-fortieth of the panel length.

(*d*) *Bending and Resisting Moments in Slabs.*—If a vertical section of a slab be taken across a panel along a line midway between columns, and if another section be taken along an edge of the panel parallel to the first section, but skirting the part of the periphery of the column capitals at the two corners of the panels, the moment of the couple formed by the external load on the half panel, exclusive of that over the column capital (sum of dead and live loads) and the resultant of the external shear or reaction at the support at the two column capitals (see Fig. 1), may be found by ordinary static analysis. It will be noted that the edges of the area here considered are along lines of zero shear, except around the column capitals. This moment of the external forces acting on the half panel will be resisted by the numerical sum of (*a*) the moment of the internal stresses at the section of the panel midway between columns (positive resisting moment)

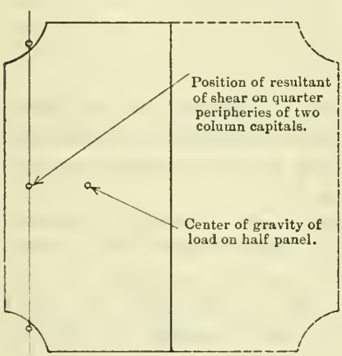

FIG. 1.

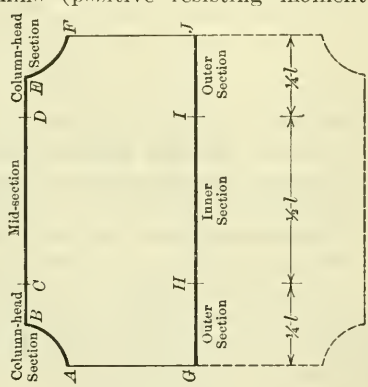

FIG. 2.

and (*b*) the moment of the internal stresses at the section referred to at the end of the panel (negative resisting moment). In the curved portion of the end section (that skirting the column), the stresses considered are the components which act parallel to the normal stresses on the straight portion of the section. Analysis shows that, for a uniformly distributed load, and round columns, and square panels, the numerical sum of the positive moment and the negative moment at the two sections named is given quite closely by the equation

$$M_x = \frac{1}{8}\ wl\ \left(l - \frac{2}{3}c\right)^2 .$$

In this formula and in those which follow relating to oblong panels,

w = Sum of the live and dead loads per unit of area;

l = Side of a square panel measured from center to center of columns;

l_1 = One side of the oblong panel measured from center to center of columns;

l_2 = Other side of oblong panel measured in the same way;

c = Diameter of the column capital;

M_x = Numerical sum of positive moment and negative moment in one direction;

M_y = Numerical sum of positive moment and negative moment in the other direction.

(See paper and closure, "Statical Limitations upon the Steel Requirement in Reinforced Concrete Flat Slab Floors", by John R. Nichols, Jun. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXVII.)

For oblong panels, the equation for the numerical sum of the positive moment and the negative moment at the two sections named becomes

$$M_x = \frac{1}{8}\, w l_2 \left(l_1 - \frac{2}{3}\, c\right)^2$$

$$M_y = \frac{1}{8}\, w l_1 \left(l_2 - \frac{2}{3}\, c\right)^2$$

where M_x is the numerical sum of the positive moment and the negative moment for the sections parallel to the dimension, l_2, and M_y is the numerical sum of the positive moment and the negative moment for the sections parallel to the dimension, l_1.

What proportion of the total resistance exists as positive moment and what as negative moment is not readily determined. The amount of the positive moment and that of the negative moment may be expected to vary somewhat with the design of the slab. It seems proper, however, to make the division of total resisting moment in the ratio of three-eighths for the positive moment to five-eighths for the negative moment.

With reference to variations in stress along the sections, it is evident from conditions of flexure that the resisting moment is not distributed uniformly along either the section of positive moment or that of negative moment. As the law of the distribution is not known definitely, it will be necessary to make an empirical apportionment along the sections; and it will be considered sufficiently accurate generally to divide the sections into two parts and to use an average value over each part of the panel section.

The relatively large breadth of structure in a flat slab makes the effect of local variations in the concrete less than would be the case for narrow members like beams. The tensile resistance of the concrete is less affected by cracks. Measurements of deformations in buildings under heavy load indicate the presence of considerable tensile resistance in the concrete, and the presence of this tensile resistance acts to decrease the intensity of the compressive stresses. It is believed that the use of moment coefficients somewhat less than those given in a preceding

paragraph as derived by analysis is warranted, the calculations of resisting moment and stresses in concrete and reinforcement being made according to the assumptions specified in this report and no change being made in the values of the working stresses ordinarily used. Accordingly, the values of the moments which are recommended for use are somewhat less than those derived by analysis. The values given may be used when the column capitals are round, oval, square, or oblong.

(*e*) *Names for Moment Sections.*—For convenience, that portion of the section across a panel along a line midway between columns which lies within the middle two quarters of the width of the panel (*HI*, Fig. 2) will be called the inner section, and that portion in the two outer quarters of the width of the panel (*GH* and *IJ*, Fig. 2) will be called the outer sections. Of the section which follows a panel edge from column capital to column capital and which includes the quarter peripheries of the edges of two column capitals, that portion within the middle two quarters of the panel width (*CD*, Fig. 2) will be called the mid-section, and the two remaining portions (*ABC* and *DEF*, Fig. 2), each having a projected width equal to one-fourth of the panel width, will be called the column-head sections.

(*f*) *Positive Moment.*—For a square interior panel, it is recommended that the positive moment for a section in the middle of a panel extending across its width be taken as $\frac{1}{25} wl \left(l - \frac{2}{3} c \right)^2$. Of this moment, at least 25% should be provided for in the inner section; in the two outer sections of the panel at least 55% of the specified moment should be provided for in slabs not having dropped panels, and at least 60% in slabs having dropped panels, except that in calculations to determine necessary thickness of slab away from the dropped panel at least 70% of the positive moment should be considered as acting in the two outer sections.

(*g*) *Negative Moment.*—For a square interior panel, it is recommended that the negative moment for a section which follows a panel edge from column capital to column capital and which includes the quarter peripheries of the edges of the two column capitals (the section altogether forming the projected width of the panel) be taken as $\frac{1}{15} wl \left(l - \frac{2}{3} c \right)^2$ Of this negative moment, at least 20% should be provided for in the mid-section and at least 65% in the two column-head sections of the panel, except that in slabs having dropped panels at least 80% of the specified negative moment should be provided for in the two column-head sections of the panel.

(*h*) *Moments for Oblong Panels.*—When the length of a panel does not exceed the breadth by more than 5%, computation may be made

on the basis of a square panel with sides equal to the mean of the length and the breadth.

When the long side of an interior oblong panel exceeds the short side by more than one-twentieth and by not more than one-third of the short side, it is recommended that the positive moment be taken as $\frac{1}{25} w l_2 \left(l_1 - \frac{2}{3} c\right)^2$ on a section parallel to the dimension, l_2, and $\frac{1}{25} w l_1 \left(l_2 - \frac{2}{3} c\right)^2$ on a section parallel to the dimension, l_1; and that the negative moment be taken as $\frac{1}{15} w l_2 \left(l_1 - \frac{2}{3} c\right)^2$ on a section at the edge of the panel corresponding to the dimension, l_2, and $\frac{1}{15} w l_1 \left(l_2 - \frac{2}{3} c\right)^2$ at a section in the other direction. The limitations of the apportionment of moment between inner section and outer section and between mid-section and column-head sections may be the same as for square panels.

(*i*) *Wall Panels.*—The coefficient of negative moment at the first row of columns away from the wall should be increased 20% over that required for interior panels, and likewise the coefficient of positive moment at the section half way to the wall should be increased by 20 per cent. If girders are not provided along the wall, or the slab does not project as a cantilever beyond the column line, the reinforcement parallel to the wall for the negative moment in the column-head section and for the positive moment in the outer section should be increased by 20 per cent. If the wall is carried by the slab, this concentrated load should be provided for in the design of the slab. The coefficient of negative moments at the wall to take bending in the direction perpendicular to the wall line may be determined by the conditions of restraint and fixedness as found from the relative stiffness of columns and slab, but in no case should it be taken as less than one-half of that for interior panels.

(*j*) *Reinforcement.*—In the calculation of moments, all the reinforcing bars which cross the section under consideration and which fulfill the requirements given under Paragraph (*l*) of this chapter may be used. For a column-head section, reinforcing bars parallel to the straight portion of the section do not contribute to the negative resisting moment for the column-head section in question. In the case of four-way reinforcement, the sectional area of the diagonal bars multiplied by the sine of the angle between the diagonal of the panel and the straight portion of the section under consideration may be taken to act as reinforcement in a rectangular direction.

(*k*) *Point of Inflection.*—For the purpose of making calculations of moments at sections away from the sections of negative moment

and positive moment already specified, the point of inflection on any line parallel to a panel edge may be taken as one-fifth of the clear distance on that line between the two sections of negative moment at the opposite ends of the panel indicated in Paragraph (*e*) of this chapter. For slabs having dropped panels, the coefficient of one-fourth should be used instead of one-fifth.

(*l*) *Arrangement of Reinforcement.*—The design should include adequate provision for securing the reinforcement in place, so as to take, not only the maximum moments, but the moments at intermediate sections. All bars in rectangular bands or diagonal bands should extend on each side of a section of maximum moment, either positive or negative, to points at least twenty diameters beyond the point of inflection, as defined herein, or be hooked or anchored at the point of inflection. In addition to this provision, bars in diagonal bands used as reinforcement for negative moment should extend on each side of a line drawn through the column center at right angles to the direction of the band at least a distance equal to thirty-five one-hundredths of the panel length, and bars in diagonal bands used as reinforcement for positive moment should extend on each side of a diagonal through the center of the panel at least a distance equal to thirty-five one-hundredths of the panel length; and no splice by lapping should be permitted at or near regions of maximum stress, except as just described. Continuity of reinforcing bars is considered to have advantages, and it is recommended that not more than one-third of the reinforcing bars in any direction be made of a length less than the distance center to center of columns in that direction. Continuous bars should not all be bent up at the same point of their length, but the zone in which this bending occurs should extend on each side of the assumed point of inflection, and should cover a width of at least one-fifteenth of the panel length. Mere draping of the bars should not be permitted. In four-way reinforcement, the position of the bars in both diagonal and rectangular directions may be considered in determining whether the width of zone of bending is sufficient.

(*m*) *Reinforcement at Construction Joints.*—It is recommended that at construction joints extra reinforcing bars equal in section to 20% of the amount necessary to meet the requirements for moments at the section where the joint is made be added to the reinforcement, these bars to extend not less than fifty diameters beyond the joint on each side.

(*n*) *Tensile and Compressive Stresses.*—The usual method of calculating the tensile and compressive stresses in the concrete and in the reinforcement, based on the assumptions for internal stresses given in this chapter, should be followed. In the case of the dropped panel, the section of the slab and dropped panel may be considered

to act integrally for a width equal to the width of the column-head section.

(o) *Provision for Diagonal Tension and Shear.*—In calculations for the shearing stress which is to be used as the means of measuring the resistance to diagonal tension stress, it is recommended that the total vertical shear on two column-head sections constituting a width equal to one-half the lateral dimension of the panel, for use in the formula for determining critical shearing stresses, be considered to be one-fourth of the total dead and live loads on a panel for a slab of uniform thickness, and to be three-tenths of the sum of the dead and live loads on a panel for a slab with dropped panels. The formula for shearing unit stress given in the Appendix to this report may then be written $v = \frac{0.25\ W}{b\,j\,d}$ for slabs of uniform thickness, and $v = \frac{0.30\ W}{b\,j\,d}$ for slabs with dropped panels, where W is the sum of the dead and live loads on a panel, b is half the lateral dimension of the panel measured from center to center of columns, and jd is the lever arm of the resisting couple at the section.

The calculation of what is commonly called punching shear may be made on the assumption of a uniform distribution over the section of the slab around the periphery of the column capital and also of a uniform distribution over the section of the slab around the periphery of the dropped panel, using in each case an amount of vertical shear greater by 25% than the total vertical shear on the section under consideration.

The values of working stresses should be those recommended for diagonal tension and shear in Chapter VIII, Section 5.

(p) *Walls and Openings.*—Girders or beams should be constructed to carry walls and other concentrated loads which are in excess of the working capacity of the slab. Beams should also be provided in case openings in the floor reduce the working strength of the slab below the required carrying capacity.

(q) *Unusual Panels.*—The coefficients, apportionments, and thicknesses recommended are for slabs which have several rows of panels in each direction, and in which the size of the panels is approximately the same. For structures having a width of one, two, or three panels, and also for slabs having panels of markedly different sizes, an analysis should be made of the moments developed in both slab and columns, and the values given herein modified accordingly. Slabs with paneled ceiling or with depressed paneling in the floor are to be considered as coming under the recommendations herein given.

(r) *Bending Moments in Columns.*—Provision should be made in both wall columns and interior columns for the bending moment which will be developed by unequally loaded panels, eccentric loading,

or uneven spacing of columns. The amount of moment to be taken by a column will depend upon the relative stiffness of columns and slab, and computations may be made by rational methods, such as the principle of least work, or of slope and deflection. Generally, the larger part of the unequalized negative moment will be transmitted to the columns, and the column should be designed to resist this bending moment. Especial attention should be given to wall columns and corner columns.

CHAPTER VIII.

Working Stresses.

1. General Assumptions.

The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.

In selecting the permissible working stress on concrete, the designer should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class composed of different materials may have approximately the same degree of safety.

The following recommendations as to allowable stresses are given in the form of percentages of the ultimate strength of the particular concrete which is to be used; this ultimate strength is that developed at an age of 28 days, in cylinders 8 in. in diameter and 16 in. long, of the consistency described in Chapter IV, Section 2 (*d*), made and stored under laboratory conditions. In the absence of definite knowledge in advance of construction as to just what strength may be expected, the Committee submits the following values as those which should be obtained with materials and workmanship in accordance with the recommendations of this report.

Although occasional tests may show higher results than those here given, the Committee recommends that these values should be the maximum used in design.

Table of Compressive Strengths of Different Mixtures of Concrete.
(In Pounds per Square Inch.)

Aggregate	1:3*	1:4½*	1:6*	1:7½*	1:9*
Granite, trap rock................	3 300	2 800	2 200	1 800	1 400
Gravel, hard limestone and hard sandstone.....................	3 000	2 500	2 000	1 600	1 300
Soft limestone and sandstone......	2 200	1 800	1 500	1 200	1 000
Cinders	800	700	600	500	400

Note.—For variations in the moduli of elasticity see Chapter VIII, Section 8.

* Combined volume fine and coarse aggregate measured separately.

2. BEARING.

When compression is applied to a surface of concrete of at least twice the loaded area, a stress of 35% of the compressive strength may be allowed in the area actually under load.

3. AXIAL COMPRESSION.

For concentric compression on a plain concrete pier, the length of which does not exceed four diameters, or on a column reinforced with longitudinal bars only, the length of which does not exceed twelve diameters, 22.5% of the compressive strength may be allowed.

For other forms of columns, the stresses obtained from the ratios given in Chapter VII, Section 9, may govern.

4. COMPRESSION IN EXTREME FIBER.

The extreme fiber stress of a beam, calculated on the assumption of a constant modulus of elasticity for concrete under working stresses may be allowed to reach 32.5% of the compressive strength. Adjacent to the support of continuous beams, stresses 15% higher may be used.

5. SHEAR AND DIAGONAL TENSION.

In calculations on beams in which the maximum shearing stress in a section is used as the means of measuring the resistance to diagonal tension stress, the following allowable values for the maximum vertical shearing stress in concrete, calculated by the method given in the Appendix, Formula 22, are recommended:

(*a*) For beams with horizontal bars only and without web reinforcement, 2% of the compressive strength.

(*b*) For beams with web reinforcement consisting of vertical stirrups looped about the longitudinal reinforcing bars in the tension side of the beam and spaced horizontally not more than one-half the depth of the beam; or for beams in which longitudinal bars are bent up at an angle of not more than 45° or less than 20° with the axis of the beam, and the points of bending are spaced horizontally not more than three-quarters of the depth of the beam apart, not to exceed 4½% of the compressive strength.

(*c*) For a combination of bent bars and vertical stirrups looped about the reinforcing bars in the tension side of the beam and spaced horizontally not more than one-half of the depth of the beam, 5% of the compressive strength.

(*d*) For beams with web reinforcement (either vertical or inclined) securely attached to the longitudinal bars in the tension side of the beam in such a way as to prevent slipping of bar past the stirrup, and spaced horizontally not more than one-half of the depth of the beam in case of vertical stirrups and not more than three-fourths of the depth of the beam in the case of inclined members.

either with longitudinal bars bent up or not, 6% of the compressive strength.

The web reinforcement in case any is used should be proportioned by using two-thirds of the external vertical shear in Formulas 24 or 25 in Chapter X. The effect of longitudinal bars bent up at an angle of from 20 to 45° with the axis of the beam, may be taken at sections of the beam in which the bent up bars contribute to diagonal tension resistance, as defined under Chapter VII, Section 8, as reducing the shearing stresses to be otherwise provided for. The amount of reduction of the shearing stress by means of bent up bars will depend upon their capacity, but in no case should be taken as greater than 4½% of the compressive strength of the concrete over the effective cross-section of the beam (Formula 22). The limit of tensile stress in the bent up portion of the bar calculated by Formula 25, using in this formula an amount of total shear corresponding to the reduction in shearing stress assumed for the bent up bars, may be taken as specified for the working stress of steel, but in the calculations the stress in the bar due to its part as longitudinal reinforcement of the beam should be considered. The stresses in stirrups and inclined members when combined with bent up bars are to be determined by finding the amount of the total shear which may be allowed by reason of the bent up bars, and subtracting this shear from the total external vertical shear. Two-thirds of the remainder will be the shear to be carried by the stirrups, using Formulas 24 or 25 in the Appendix.

Where punching shear occurs, provided the diagonal tension requirements are met, a shearing stress of 6% of the compressive strength may be allowed.

6. BOND.

The bond stress between concrete and plain reinforcing bars may be assumed at 4% of the compressive strength, or 2% in the case of drawn wire. In the best types of deformed bar, the bond stress may be increased, but not to exceed 5% of the compressive strength of the concrete.

7. REINFORCEMENT.

The tensile or compressive stress in steel should not exceed 16 000 lb. per sq. in.

In structural steel members, the working stresses adopted by the American Railway Engineering Association are recommended.

8. MODULUS OF ELASTICITY.

The value of the modulus of elasticity of concrete has a wide range, depending on the materials used, the age, the range of stresses between which it is considered, as well as other conditions. It is recommended that, in computations for the position of the neutral

axis, and for the resisting moment of beams, and for compression of concrete in columns, it be assumed as:

(*a*) One-fortieth that of steel, when the strength of the concrete is taken as not more than 800 lb. per sq. in.

(*b*) One-fifteenth that of steel, when the strength of the concrete is taken as greater than 800 lb. per sq. in. and less than 2 200 lb. per sq. in.

(*c*) One-twelfth that of steel, when the strength of the concrete is taken as greater than 2 200 lb. per sq. in. and less than 2 900 lb. per sq. in., and

(*d*) One-tenth that of steel, when the strength of the concrete is taken as greater than 2 900 lb. per sq. in.

Although not rigorously accurate, these assumptions will give safe results. For the deflection of beams which are free to move longitudinally at the supports, in using formulas for deflection which do not take into account the tensile strength developed in the concrete, a modulus of one-eighth of that of steel is recommended.

CHAPTER IX.

Conclusion.

In the preparation of this Final Report, 21 members have taken a more or less active part; all members have agreed to it in its present form.

The Joint Committee acknowledges its indebtedness to its sub-committee on design, Professors Talbot, Hatt, and Turneaure, for their invaluable and devoted service.

The Joint Committee believes that there is a great advantage in the co-operation of the representatives of different technical societies, and trusts that a similar combination of effort may be possible, some time in the future, to review the work done by the present Committee, and to embody the additional knowledge which will certainly be obtained from further experimentation and practical experience with this important material of construction.

Respectfully submitted,

Joseph R. Worcester,
Chairman.
Emil Swensson,
Vice-Chairman.
Richard L. Humphrey,
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SPENCER B. NEWBERRY,
EDWARD GODFREY,*
EGBERT J. MOORE,
LEONARD C. WASON.

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* Mr. Godfrey dissents from the portion of the Report relating to stirrups and their treatment. He would give stirrups and short shear members no recognition, for the reason that he holds that they have not shown themselves to have any definite value in tests, and that analysis fails to show that any definite value can be ascribed to them ; he also believes that dependence on stirrups to take end shear has resulted in much unsafe construction and some failures. He would take care of diagonal tension by bending up some of the main reinforcing rods and anchoring them for their full tensile strength beyond the edge of support. He recommends that bends be made close to the supports for the upper bends and at quarter points for the lower bends in beams carrying uniform load. For girders carrying beams bends should be made under the beams. For anchorage he recommends that the rod should extend 40 to 50 diameters beyond the point where it intersects a line drawn, at 45° with the horizontal, from the bottom of the beam at the face of the support.

He recommends that the stress in bent-up rods be assumed to be that obtained by multiplying the excess of shear over that taken by the concrete (at 40 or 50 lb. per sq. in.) by the secant of the inclination of the rod with the vertical.

Mr. Godfrey also dissents from all parts of the Report relating to rodded columns, or columns having longitudinal rods without close-spaced hooping, for the reason that he holds that such reinforcement has not shown itself to have any definite value in tests on columns, and that analysis fails to show that any definite value can be ascribed to it, when such analysis takes into account the necessity for toughness in all columns ; he also believes that dependence on such reinforcement has led to much unsafe construction and many failures. He would recognize as reinforced concrete columns only such columns as have in addition to the longitudinal rods a complete system of close-spaced hooping. He objects to the reading of Chapter VII, Section 9, Paragraph (*b*) as being capable of interpretation that hooped columns are given an advantage in the matter of unit stresses only below ten diameters in height. He recommends the standardization of hooped columns, and suggests that columns be reinforced by a coil or hoops of round steel having a diameter one-fortieth of that of the external diameter of the column and eight upright rods wired to the same, the pitch of the coil being one-eighth of the column diameter. He would consider available for resisting compressive stress, the entire area of the concrete of a circular column or of an octagonal column, but no part of the longitudinal rods or hooping. In a square column only 83% of the area of concrete would be considered available. The compression he would recommend on columns (for 2 000-lb. concrete) would be :

$$P = 670 - 12\,\frac{l}{d}$$

where P = allowable compression, in pounds per square inch ;
l = length of column, in inches ;
d = diameter of column, in inches.

CHAPTER X.

Appendix.

SUGGESTED FORMULAS FOR REINFORCED CONCRETE CONSTRUCTION.

These formulas are based on the assumptions and principles given in the chapter on design.

1. Standard Notation.

(*a*) *Rectangular Beams.*

The following notation is recommended:

f_s = tensile unit stress in steel;
f_c = compressive unit stress in concrete;
E_s = modulus of elasticity of steel;
E_c = modulus of elasticity of concrete;
$n = \frac{E_s}{E_c}$;
M = moment of resistance, or bending moment in general;
A_s = steel area;
b = breadth of beam;
d = depth of beam to center of steel;
k = ratio of depth of neutral axis to depth, d;
z = depth below top to resultant of the compressive stresses;
j = ratio of lever arm of resisting couple to depth, d;
$jd = d - z$ = arm of resisting couple;
p = steel ratio $= \frac{A}{bd}$.

(*b*) T-*Beams.*

b = width of flange;
b' = width of stem;
t = thickness of flange.

(*c*) *Beams Reinforced for Compression.*

A' = area of compressive steel;
p' = steel ratio for compressive steel;
f_s' = compressive unit stress in steel;
C = total compressive stress in concrete;
C' = total compressive stress in steel;
d' = depth of center of compressive steel;
z = dèpth to resultant of C and C'.

(*d*) *Shear, Bond and Web Reinforcement.*

V = total shear;
V' = total shear producing stress in reinforcement;
v = shearing unit stress;
u = bond stress per unit area of bar;
o = circumference or perimeter of bar;
Σo = sum of the perimeters of all bars;
T = total stress in single reinforcing member;
s = horizontal spacing of reinforcing members.

(*e*) *Columns.*

A = total net area;
A_s = area of longitudinal steel;
A_c = area of concrete;
P = total safe load.

2. Formulas.

(*a*) *Rectangular Beams.*

Position of neutral axis,

$$k = \sqrt{2pn + (pn)^2} - pn \quad \ldots\ldots (1)$$

Arm of resisting couple,

$$j = 1 - \frac{1}{3}k \quad \ldots\ldots (2)$$

[For f_s = 15 000 to 16 000 and f_c = 600 to 650, j may be taken at $\frac{7}{8}$.]

Fiber stresses,

$$f_s = \frac{M}{A_s jd} = \frac{M}{pjbd^2} \quad \ldots\ldots (3)$$

$$f_c = \frac{2M}{jkbd^2} = \frac{2pf_s}{k} \quad \ldots\ldots (4)$$

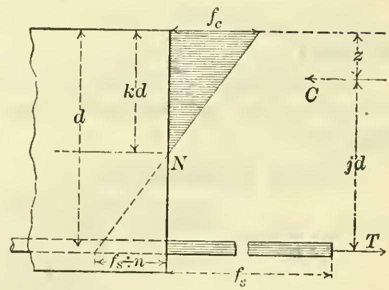

Fig. 3.

Steel ratio, for balanced reinforcement,

$$p = \frac{1}{2} \frac{1}{\frac{f_s}{f_c}\left(\frac{f_s}{nf_c} + 1\right)} \quad \ldots\ldots (5)$$

(*b*) **T**-*Beams.*

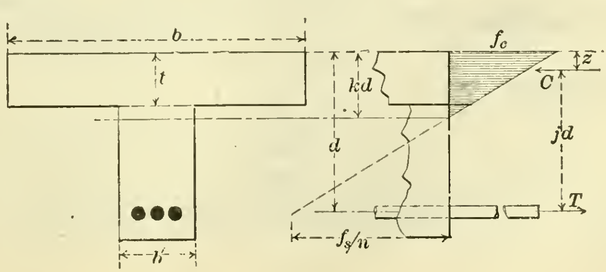

Fig. 4.

Case I. When the neutral axis lies in the flange, use the formulas for rectangular beams.

Case II. When the neutral axis lies in the stem.

The following formulas neglect the compression in the stem.

Position of neutral axis,

$$kd = \frac{2\,ndA_s + bt^2}{2\,nA_s + 2\,bt} \quad \text{(6)}$$

Position of resultant compression,

$$z = \frac{3\,kd - 2\,t}{2\,kd - t} \cdot \frac{t}{3} \quad \text{(7)}$$

Arm of resisting couple,

$$jd = d - z \quad \text{(8)}$$

Fiber stresses,

$$f_s = \frac{M}{A_s jd} \quad \text{(9)}$$

$$f_c = \frac{Mkd}{bt(kd - \frac{1}{2}t)jd} = \frac{f_s}{n} \cdot \frac{k}{1-k} \quad \text{(10)}$$

(For approximate results, the formulas for rectangular beams may be used.)

The following formulas take into account the compression in the stem; they are recommended where the flange is small compared with the stem:

Position of neutral axis,

$$kd = \sqrt{\frac{2\,ndA_s + (b - b')\,t^2}{b'} + \left(\frac{nA_s + (b - b')\,t}{b'}\right)^2} - \frac{nA_s + (b - b')\,t}{b'} \quad \text{(11)}$$

Position of resultant compression,

$$z = \frac{(kdt^2 - \frac{2}{3}\,t^3)b + [(kd - t)^2\,(t + \frac{1}{3}\,(kd - t))]b'}{t(2\,kd - t)b + (kd - t)^2\,b'} \quad \text{(12)}$$

Arm of resisting couple,

$$jd = d - z \quad \text{(13)}$$

Fiber stresses,

$$f_s = \frac{M}{A_s jd} \quad \text{(14)}$$

$$f_c = \frac{2\,Mkd}{[(2\,kd - t)bt + (kd - t)^2\,b']jd} \quad \text{(15)}$$

(*c*) *Beams Reinforced for Compression.*

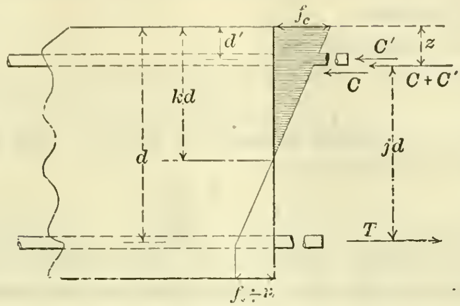

FIG. 5.

Position of neutral axis,

$$k = \sqrt{2\,n\left(p + p'\,\frac{d'}{d}\right) + n^2(p + p')^2} - n(p + p') \ldots\ldots (16)$$

Position of resultant compression,

$$z = \frac{\frac{1}{3}\,k^3 d + 2\,p'nd'\left(k - \frac{d'}{d}\right)}{k^2 + 2\,p'n\left(k - \frac{d'}{d}\right)} \ldots\ldots (17)$$

Arm of resisting couple,

$$jd = d - z \ldots\ldots (18)$$

Fiber stresses,

$$f_c = \frac{6M}{bd^2\left[3\,k - k^2 + \frac{6p'n}{k}\left(k - \frac{d'}{d}\right)\left(1 - \frac{d'}{d}\right)\right]} \ldots\ldots (19)$$

$$f_s = \frac{M}{pjbd^2} = n\,f_c\frac{1 - k}{k} \ldots\ldots (20)$$

$$f_s' = n\,f_c\,\frac{k - \frac{d'}{d}}{k} \ldots\ldots (21)$$

(*d*) *Shear, Bond, and Web Reinforcement.*

For rectangular beams,

$$v = \frac{V}{bjd} \ldots\ldots (22)$$

$$u = \frac{V}{jd\,.\,\Sigma o} \ldots\ldots (23)$$

[For approximate results j may be taken at $\frac{7}{8}$.]

The stresses in web reinforcement may be estimated by means of the following formulas:

Vertical web reinforcement,

$$T = \frac{V's}{jd} \qquad \text{(24)}$$

Bars bent up at angles between 20 and 45° with the horizontal and web members inclined at 45°,

$$T = \frac{3}{4}\frac{V's}{jd} \qquad \text{(25)}$$

In the text of the report it is recommended that two-thirds of the external vertical shear (total shear) at any section be taken as the amount of total shear producing stress in the web reinforcement. V' therefore equals two-thirds of V.

The same formulas apply to beams reinforced for compression as regards shear and bond stress for tensile steel.

For T-Beams,

$$v = \frac{V}{b'jd} \qquad \text{(26)}$$

$$u = \frac{V}{jd \,.\, \Sigma o} \qquad \text{(27)}$$

[For approximate results j may be taken at $\frac{7}{8}$.]

(*e*) *Columns.*

Total safe load,

$$P = f_c\,(A_c + nA_s) = f_cA(1 + (n-1)p) \qquad \text{(28)}$$

Unit stresses,

$$f_c = \frac{P}{A(1 + (n-1)p)} \qquad \text{(29)}$$

$$f_s = n\,f_c \qquad \text{(30)}$$

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

REPORT OF THE SPECIAL COMMITTEE TO FORMULATE PRINCIPLES AND METHODS FOR THE VALUATION OF RAILROAD PROPERTY AND OTHER PUBLIC UTILITIES*

COMMITTEE:

Frederic P. Stearns, *Chairman,*

Charles S. Churchill, Henry E. Riggs,

William G. Raymond, Jonathan P. Snow,

William J. Wilgus,

Leonard Metcalf, *Secretary.*

OCTOBER 28TH, 1916.

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* To be presented to the Annual Meeting, January 17th, 1917.

NOTE: This Report is here published in order to get it before the Society as early as possible, but as there is so little time before, and available at the Annual Meeting, the Committee suggests that the discussion be continued in writing and published in *Proceedings,* and that the Report be finally presented to the Society at the next Annual Convention.—(*Secretary.*)

PREFACE.

In presenting this report to the Members of the American Society of Civil Engineers, the Committee is fully alive to the fact that the art of valuation is still in formative condition, as is evidenced by the conflicting views expressed, or principles enunciated, even by the higher Courts. That debatable subjects arise frequently, and will continue to do so, is indicated by the record of the Committee's work incident to the rendering of this report, for in spite of the prior knowledge of its members on this subject, and professional experience in it, five years have elapsed since their appointment, in which forty-eight joint meetings have been held, many of them consisting of three sessions, and a voluminous correspondence has been carried on, aggregating thirteen substantial volumes.

Nevertheless, the fact that nine men of widely different training and experience, practising in different professional lines and fields, have been able to come finally to common belief upon most of the subjects discussed—the principles which should control the valuation of normal public utility properties—leads the Committee to hope that this report may be helpful to others, and may serve to clarify this very involved subject, to the common advantage of public service corporations and the public served, by aiding in the establishing of procedure and in the reducing of the uncertainties of valuation and rating of public utility properties.

Where differences of opinion have developed, the conflicting views of the Court have been cited, the effect of the application of different theories indicated, and the course of action most likely to lead to a fair settlement of debatable questions has been outlined.

The Committee bespeaks a thorough and open-minded study of the whole report, by the members of the Society interested in the subject. Only with such a background will its full significance be apparent. The subject is so involved and many-sided that brevity and conciseness are not always possible, and that brief statements may not always be capable of isolation from the context without the possibility of causing ambiguity; therefore, though the Committee has prepared an abstract of its conclusions for the convenience of the readers of the report, it hopes that the members of the Society will base their conclusions and discussions on the main report, rather than on the abstract.

The table of contents follows. Thereafter are given, successively, the abstract, the introduction and other chapters of the report, and finally a detailed glossary.

OCTOBER 28TH, 1916.

CONTENTS.

The above Appendices were not received in time to publish with this report; they will be published later.

ABSTRACT OF REPORT.

The Committee, in its consideration of the subject assigned to it. has been guided by the belief that stress should be laid on fundamental principles and on general methods rather than on details which necessarily vary under different circumstances; that the discussions, unless otherwise stated, should be confined to normal properties; that valuation should have its foundation in fact; that where there are alternative methods equally fair to the parties affected, the one should be selected which is most capable of being carried out effectively under present laws, as defined by the Courts, and which is most desirable for general use in the direction of uniformity; that recognition should be given to the interdependence of the various elements which enter into the problem; that while major attention should be given to the ascertainment of the eost of creating the property in question and its business, due consideration should be given to intangible values, and that the important item of interest, in this report meaning interest compounded annually, should always be considered.

In the light of this preliminary understanding and of the discussions which ensued, the following conclusions have been reached.

Fundamental Principles of Valuation.

The principles and methods must be such that when properly applied the result will be fair to all parties affected and of a nature that will attract to the service of the public capital necessary for building new properties and for improving and extending old ones.

New Properties.—In the valuation of a new property, if the question of a fair return is at stake, the actual investment in the portion devoted to public use, including working capital and development expense, should be taken as the basis for "fair value"; if the same property just ready for operation is to be valued for public acquisition, the basis of "fair value" should be the actual cost, including the money value of services and other considerations involved; if the valuation is to be used for capitalization, the result should be attained in the same way as the return base, except that all parts of the property should be included; and if for taxation, whether of a new or old property, the result must accord with the laws of the State, or, where not governed by such laws, should, to make it equitable, be fixed at a sum consistent with the valuation of other property for taxation.

Old Properties Under Continuous Regulation.—In the valuation of an old property, operating without competition and from its inception under commission control as to rates and methods of accounting, and assumed to have been entitled to earn sums sufficiently large to provide for all expenses of maintenance, operation and taxation, depreciation allowanees, and a fair return on the "fair value" of the prop-

erty, the owner should be compensated in some way for losses that he may have sustained during the early years of operation before the property was tuned up and the business developed, either by including in the valuation the sum of the deficiency of earnings in the early years, with interest, or by allowing higher rates of return in subsequent years to offset the early deficiency.

Old Properties Not Under Continuous Regulation.—In the valuation of an old property which has not been subject to continuous regulation, not only are the foregoing principles important, but there are many cases in which equity calls for the inclusion of not only the sum representing the sacrifice by the owner but also a further positive or negative sum representing valuable property or rights which may have been acquired or lost by the owner as a result of time or through the failure of the public or the owner to assert their authority, the Courts holding that the present value of the property should be used rather than its cost.

Physical Property to be Included in Valuation.

This varies in different cases with the use to which the valuation is to be put and the law governing the case.

Used and Unused Property.—In cases of rate regulation, only the property considered to be devoted to public use should be included, embracing that which is in active use and also that which is properly and reasonably held in reserve to insure the safety, economy, sufficiency, and continuity of service. In valuations for capitalization and public acquisition it is obvious that all of the property in question should be included.

Retired or Discarded Property.—Plant units which have been definitely abandoned and are not likely again to be used, due to having been worn out in service or by reason of the reconstruction of the property, should be excluded from the valuation and should appear either in a separate schedule of retired or discarded property, or such full statement of the conditions should be made as will definitely fix the status of the units or parts. Temporary works necessarily built in connection with, or required for, the construction of permanent works, or for furnishing service to the public at an earlier date than it could be furnished by the permanent works, should be included in the valuation.

Excessive Size or Capacity.—No reduction should be made in the valuation on account of excessive size or capacity, except when the excess is so great as to be clearly unreasonable and is the result of not using proper foresight.

Donated Property.—Lands or other property voluntarily donated to a public utility should be included when determining the reproduction cost, on the same basis as land and property otherwise acquired.

Leased Property.—In the case of leased property, either the property itself or the lease should be valued, as circumstances may dictate.

Title to Property Not Conclusive.—Structures located on land to which the owner of a public utility has no title should be *included* in the valuation of the property where the owner has been required by law or necessity to pay their cost, including in this class also property voluntarily donated; and they should be *excluded* where other public service companies, the public, or the users, other than the owner in question, have been required by law or necessity to pay their cost.

Working Capital.—It is customary to include under the term "working capital" the amount of cash, materials, and supplies, provided for use in the plant, but not yet forming a part of it, and other current assets which are essential for the proper maintenance, operation, and administration of a property. There should be included in a valuation an amount of working capital sufficiently large, not only to meet the usual requirements, but to provide for emergencies.

Securities Owned.—Ordinarily, the valuation of property devoted to public use should not include securities owned, or surplus cash not forming a part of working capital, except in instances where such securities and surplus cash are an offset, in whole or in part, for depreciation deducted from the cost of the property.

Original Cost to Date.

As defined by the Committee, this is the first cost of the identical property units now in use, including overhead charges.

Difficulties.—While much of the difficulty of determining original cost as thus defined in some cases may be removed, especially in the case of short-lived property, it is not feasible to obtain a dependable result where the absence of reliable historic data makes necessary a resort to estimates, as in the case of old properties consisting mainly of long-lived items.

Schedule.—Generally, it will be found necessary to prepare a schedule in the same way that one would be made for determining the cost of reproduction, many adjustments in the records often being required, even under the most favorable conditions, in order to obtain correct results.

Costs—Unit Costs.—When a schedule is necessary, the corresponding costs or unit costs are essential to the completion of the inventory, and where these are unobtainable, as is usually true in the case of property units acquired or created long ago, the ascertainment of the original cost is impossible.

Overhead Charges.—These are recited at length in the section relating to cost of reproduction. They are inadequately reflected in the records, as a rule, and therefore adjustments are required which are largely matters of opinion and speculation, and which, in conse-

quence, make more uncertain the final result thus often destroying its usefulness.

Development Expense.—The expense, actually incurred in connection with the tuning up and creation of the business of a property, should be included as a part of the original cost to date.

Cost of Reproduction.

Theory of Reproduction.—Estimates of the cost of reproduction should be based on the assumption that the identical property is to be reproduced, rather than a substitute property; that while apparent present-day conditions, that would affect the cost of reproducing the property, must be considered in any logical estimate, yet history must also be considered, to determine what is to be reproduced, the conditions under which it is to be reproduced, and how the estimates must be made; that for all those items concerning which there can be no doubt the engineer should use the basis plainly applying, and that for those that are doubtful, or have been questioned, he should present the effect of the use of the different bases clearly, that the determining body may have the data for a wise decision; and that normal present conditions shall determine the prices and methods for doing the work.

Preliminary Work.—The first step in estimating the reproduction cost of a property is such a study of the property and its history as will enable the estimator to make a complete list of all items, lay out a proper financial and construction programme, and fix proper unit prices to the several items of the schedule, after which the property should be divided into groups of items or units which will lend themselves to the depreciation study and accounting, preferably following some well established classification of accounts.

The field schedules and inventories, suitably recorded on appropriate forms, should be based not only on full and complete surveys and inspections of the visible physical property, but they should also reflect a careful historical search of existing records of original conditions, and other reliable sources of information, bearing on items of material or work which entered into or were incidental to actual existing units, special care being exercised to exclude that which is not capable of definite proof, and to limit the speculative uncertainties as far as possible.

Unit Prices.—In determining unit prices a rational sequence of construction should be assumed for the reproduction of a property; and rational assumptions should be made as to the manner of doing the different parts of the work, whether by the forces of the company or by contract. Unit prices based, where possible, on the actual cost of doing similar work, in a similar manner, under similar circumstances, should be determined by persons of experience and sound judgment. They should be based on the normal average cost of work

for a considerable period—say, 5 or 10 years—in order to give stability to the valuation, so that it may be used for a subsequent term of years. In the case of items which are steadily increasing or decreasing in value, the prices adopted should be normal for the time of the valuation. Full consideration should be given to the time allowed for construction, to climatic conditions, and to the effect of any other significant conditions or limitations upon the cost of the work.

Land Holdings.—Separate parcels of land, such as one or two lots, or a tract of not unusual size, not connected with other lands of the utility in a strip or body, and where freedom of choice in selection may be exercised, should be valued on the same basis as other lands in the vicinity, used for general purposes.

Where large tracts have been acquired, made up of a number of separate entire parcels, the history of the transaction should be completely investigated and allowance made in the estimate for costs of vacation of streets, or acquisition of other rights, incident to the use of the property as a whole. Such further allowances should be made, as may seem to be justified by experience, to cover excess costs, over and beyond the normal market values which existed at the beginning of the project, and which were due to fluctuations of price or other causes beyond control. Normal market values of similar and near-by property, as of the time of appraisal, should be the basis, with such additions as are warranted by the investigation in each case.

In the consideration of values of lands, for rights of way for a railroad, an electric railroad, an aqueduct, or other like property, or, lands for a water-works or an hydro-electric reservoir, where freedom of choice is restricted and where all the land must be acquired, radically different methods must prevail.

In the valuation of lands of this class, a clear distinction should be made between:

(*a*) Lands where the entire tract or parcel is taken and there is no element of severance damages;

(*b*) Lands where only a portion of the tract is taken and where the element of severance damages is present;

and the extent of lands of both classes should be shown.

Historic conditions, where ascertainable, should be given due weight in fixing the extent and character of the severance. All elements of value to the seller, including recognition of all damages to the portions of his property not taken, which would prevail in the case of condemnation of the lands under reproduction, should be considered.

A determination of the relation existing between actual recent acquisition costs and the normal market value of the lands out of which the strip or parcel was taken at the time of acquisition is undoubtedly possible in many cases. It would seem that where such relation can

be determined, its use in connection with the normal market values of these or similar lands at the time of appraisal should establish a reasonable cost of reproduction.

The determination of the figure to be used should be based in all cases on full consideration of the present normal market value of the area of land acquired and of other recent purchases by the same or other companies of similar lands in the vicinity or in districts of like characteristics; the damage to the remaining land, not required, due to severance and all consequential injuries; the amount and character of the costs of acquisition and overhead charges; enhanced prices due to active demand; and any other real items of cost which would be included in case of purchase. But no allowance should be included for special values coming after the acquisition of the property on account of its new use or on account of a greater earning power under the new use, or for any other hypothetical "value".

Estimates should be based on prices and values as of the time of appraisal, be they higher or lower than those prevailing at the time of original acquisition. The thing sought in reproduction is the fair cost of acquiring the property as of the date of valuation.

The treatment of the valuation of land holdings is not yet thoroughly crystallized; therefore the valuing engineer will do well to confer with counsel upon the interpretation of past Court decisions and the legal principles which are most fairly applicable to the case under review.

Overhead Charges.—There are certain expenses called overhead charges, inseparable from the construction of any property, which are a necessary and proper part of its cost, but which are not capable of physical identification after the completion of construction work. These expenses cannot be covered in the estimate of "Cost of Reproduction" by the application of specific unit prices; from their nature they attach to the whole or large parts of the property rather than to any particular units.

Among the expenditures which must be provided for, and classed as overhead charges are:

(*a*) Cost of promotion;

(*b*) Cost of financing and securing the necessary capital with which to carry out the enterprise;

(*c*) Cost of organization, including the incorporation and organization of the company, securing of franchises, and other like expenditures;

(*d*) Engineering, including the making of the preliminary investigations and plans, plans for the construction of the entire property, the engineering supervision of all construction and other work involved in the development of a property, except

such direct supervision as may properly be included in the unit prices of various property units, or as specific charge against some particular schedule or group of units;

(*e*) Administration, including salaries for general officers, agents, accountants, clerks, and other assistants, not included in the engineering and legal departments, and all administration expenses;

(*f*) Legal, including salaries and expenses of law officials and costs of litigation which, depending on the character of the property and its location, may be a comparatively minor item or a very large one;

(*g*) Interest during the period of construction, on money borrowed, or on money invested in the property by its owners;

(*h*) Taxes and insurance during construction; and

(*i*) Contingencies, representing expenditures which cannot be foreseen but which from one cause or another are always of considerable size in the construction or reproduction cost estimate of any great enterprise.

Depreciation and Appreciation.

With a desire to remove the ambiguity and resulting confusion that has attended the use of the term "depreciation" in connection with valuation, the Committee has considered the subject from three standpoints: (1) the cause, *decretion* or loss of service life; (2) the record, *accounting depreciation*, or the money allowance made in bookkeeping to offset accruing loss of service life; and (3) the amount sought, *depreciation of valuation* or *fair depreciation*, the sum which should be deducted from original cost to date or from estimated cost of reproduction new as a step in finding that which the Courts have called "fair value".

Decretion.—This is the fact of loss of service life of a physical property, or property unit, or item, regardless of its effect on value or anything else. It may be due to use, or inadequacy, or obsolescence or accident, either singly or in combination in a given plant or plant unit.

Although, in a well-maintained property, decretion is always present in some degree, yet in some cases this decretion, converted into loss of value, which loss is hereafter called cost of decretion, should not be considered to be a deductible quantity in finding the value of the property—that is, it should not be considered as *depreciation of valuation*, or *fair depreciation*. Unfortunately, this has not been entirely understood.

Whether or not, and to what extent, if any, the loss of value due to existing decretion shall be deducted from original cost to date or cost

of reproduction new, when finding "fair value" for any purpose, is the great troublesome problem of depreciation in valuation.

Accounting Depreciation.—The fundamentals of the methods of accounting for depreciation are that the owner of a public utility is under obligation to the investors in its securities to maintain the integrity of the investment as a continuing property and to furnish suitable service to the public; that the public is under obligation to the owner to pay a fair price for the service rendered, which should cover all operating expenses, a proper allowance for depreciation and a fair return upon the "fair value" of the property; and that the return to the investor and the rates to the consumer should be kept reasonably stable and uniform from year to year and should be fair.

The four accounting methods in use for accounting for depreciation, the *replacement method,* the *straight-line method,* the *compound-interest method* (formerly called by the Committee the "equal-annual-payment method"), and the *sinking-fund method,* yield identical total costs when the whole life of a property unit is considered, and any one of them seeming to be the most convenient may be chosen, provided only that under the circumstances it is legal, safe, and fair.

The replacement method is applicable to those short-lived properties or parts of properties made up of a large number of items, the replacement or retirement of which proceeds after a time with fair regularity and causes no troublesome variations in return or service rates; the straight-line method applies to any property units having more than a year of service life, which are assumed to depreciate uniformly from the beginning to the end of service life; the compound-interest and sinking-fund methods apply to property units the depreciation of which is assumed to progress at the same rate as a sinking fund grows from an annuity, accumulating at compound interest.

In addition to these four methods there is the unit cost method, eminently sound in theory but not readily applicable to accounting purposes, which is based on the conception that the value of a plant unit should be decreased from year to year to such an extent that the cost per unit of output or service, taking into account all annual charges for interest, depreciation, repairs, cost of operating, etc., should be constant during each year of the estimated service life of the unit.

The great discrepancy in the growth of depreciation of long-lived units under the straight-line and compound-interest theories should be carefully noted when determining which method to use.

This report is particularly concerned with depreciation accounting as it relates to valuation, and the determination of the depreciation of valuation. It would seem to be fair in any given case to give the method of accounting used by the utility in setting up depreciation

allowances its proper effect in determining deductible depreciation or the depreciation of valuation.

Depreciation of Valuation Dependent on Accounting Methods and Regulations.—Finding the cost of decretion, here defined as the loss of service life of an item converted into loss of value, is a step in the determination of depreciation, but whether and to what extent, if at all, the estimate thus found shall be treated as depreciation of valuation may be, and very probably will be, dependent, at least in part, on the methods of accounting for depreciation and the character of regulation that have prevailed.

Depreciation of Valuation under Replacement Method.—If by order or sanction of a regulating body, or by long-continued proper custom under no regulation, a property, as for instance a railroad, has been maintained in normal working condition, necessarily less than new in some or all of its parts, by the replacement method, and at any given date is being valued for any public purpose and at that date shows normal condition, all its several parts being in as good condition as could be expected, the accounts showing that those amounts have been expended in renewals that were necessary to keep the property in normal working condition, and the fact appearing that no expenditure reasonably to be expected could put the property in better than the normal condition in which it is found, and that no unusually large expenditure is presently to be necessary for this purpose, then, in spite of the fact that there is an existing decretion in its several parts, there should be found no depreciation of valuation. Under the method of accounting, the public has not paid, and could not pay, for the accrued depreciation, and under this condition its accrued obligation to pay should be considered an asset of the company owner.

If parts of the property are maintained under the replacement method and part by some proper allowance method, except as noted below, then depreciation of valuation should be found with respect to those parts maintained under the allowance method, but this depreciation of specific physical units will be made good in whole or in part by existing funds or property purchased with allowances, either or both of which will be included in the valuation as they are found.

If in the judgment of the valuing engineer, the replacement method may not be used with propriety for a given property, either because not in accordance with law, or because the method is not adapted to the property, then, whether or not the property has been maintained in the past under this method, the valuing engineer should estimate depreciation of valuation in the amount of the cost of the decretion he finds. There can be no certainty that the property will be properly maintained in the future.

When a comparatively new property, other than a railroad, is to be valued, and it has not been under any regulation that has affected

its accounting methods, the law as laid down in the Knoxville decision would seem to make it necessary to find depreciation of valuation in amount equal to the cost of decretion found for all items, whether or not maintained by the replacement method. The Committee, however, believes that this may work hardship and injustice in some instances, and suggests that in such cases the facts be reported with such recommendations as to equity, as may seem fair to the engineer.

Depreciation of Valuation under Allowance Methods.—If either the straight-line, compound-interest, or sinking-fund method has been used in computing depreciation, and the method of accounting for it has been prescribed by a regulating body or voluntarily followed by a company owner from the beginning, the same theory, so far as it applies to the property in question, should be used for estimating the cost of decretion; and the entire cost so found, lessened by any accumulated depreciation funds, will appear as depreciation of valuation, unless the sinking-fund method of accounting has been used. In the latter case, if the valuation has to do with the reasonableness of the return and the accounting is to go on as before, apparently existing depreciation would not be *depreciation of valuation*, and therefore would not be deductible; but if the valuation has to do with condemnation or purchase, then, as in other cases, the apparently existing depreciation is depreciation of valuation, and the owner should receive the depreciated value of the physical property and the existing fund.

Effect of Regulation on Depreciation of Valuation.—Regulation which determines the method of accounting will in part determine the amount of depreciation of valuation when finding "fair value", because it determines the method by which the public shall pay for the loss of service life. If the regulating body has prescribed the replacement method for the whole period that units have been in existence, then, although depreciation may exist, it is not depreciation of valuation, because, under the method of accounting, the public has not paid, and could not pay, for the accruing depreciation, and is still under obligation to pay for it.

Methods of accounting in force at the present time which make proper provision for the accruing depreciation should not have full weight, if, in previous years during the life of the property units, other methods were in use which did not make provision for such depreciation. The amount of depreciation of valuation in such cases should be equivalent to the accumulated contributions of the public for depreciation allowances under the various methods of accounting which have affected the property unit from time to time. The public is still under obligation to make good that part of the loss of service life not yet paid for, and this obligation should be considered to be as much the property of the company usable to offset accrued depreciation as renewal funds or property actually in existence.

Whether or not this reasoning will stand in any case is for the Court to determine. Valuing engineers and accountants should report what they find as to the actual cost of decretion, and the sums which have been received to offset such cost, under the methods prescribed by the regulating body from time to time. They may give their opinions as to the amount of depreciation that should be deducted from cost to find cost less depreciation as an element in the quantity known as "fair value".

If regulation has not fixed accounting methods, but has limited the earnings, it should be permissible to inquire whether the limited earnings have been sufficient to pay operating expense, depreciation, and fair return. If so, depreciation found should be considered depreciation of valuation to the extent warranted by the accounting methods lawfully or properly followed; if not, a question arises. It is remembered that the duty of the company owner is first to maintain the property "before coming to the question of profit at all", and that it is the duty of the regulating body to see that rates are such as to permit the company owner to earn operating expense, depreciation, and fair return. If the regulating body has made sufficient earnings impossible, is it still the duty of the company owner to maintain the property before paying fair return to its security holders? If it is, depreciation of valuation should be found in the amount of the total cost of decretion or so far as warranted by the accounting methods followed. If not, depreciation found should not be considered depreciation of valuation except to the extent covered by earnings after deducting operating expense and fair return. This is a matter of equity to be determined by a Court. If under regulation the property is a losing venture, it is not included in the class of properties now being considered. In any event the depreciation existing should be found and reported, together with all pertinent facts, that the Court may determine the equities of the case.

Conclusion upon Depreciation.—The valuing engineer should bear in mind that when a company owner has invested a reasonable sum in a property for public service, it is entitled to, but not guaranteed, a fair return on its investment, so long as the money remains in the property, either as property, or funds, or accrued public obligation to pay. Therefore, so long as the company owner keeps a sum equivalent to the total investment at work for the public, either as property serving the public, or funds held in reserve for such property, no policy should be followed in estimating depreciation that will reduce the property to a value less than the investment, or, when using cost of reproduction less depreciation, as a basis of "fair value", to a value less than the cost of reproduction of that part of the property estimated to have been created with company funds, acquired by gift, or in any way not the result of public contributions to cover depreciation.

Appreciation.—Appreciation, largely the result of solidification, seasoning and adaptation, represents the improvement in quality and usefulness of certain parts of the physical properties of a railroad or other public utility property, and it results from the lapse of time, from work not specifically charged to capital account, from maintenance, from use, etc., and covers items, not represented either by the quantities or unit prices, that are determined in connection with a valuation.

There should be no general setting off of appreciation against depreciation, but appreciation should be determined independently from depreciation. Care must be taken that items of labor and expense included in the estimate may not be duplicated in development expense.

Development Expense.

In the production of a normal going property, development expense, almost invariably, is an unavoidable real cost, and is measured by the difference between the amount which the company is entitled to earn in the early years and the amount which it actually does earn. The portion of this expense incurred in tuning up the property and bringing it to its present state of operating efficiency may be included in the cost of construction, and the remainder may be treated as the cost of acquiring the business.

Intangible Value.

The intangible value that pertains to a property and should be given due weight in the ascertainment of "fair value" is the difference between the tangible value—that is to say, proper cost including development expense, less depreciation of valuation—and exchange value, in which is reflected existing and potential dependable income and beneficial results. It embraces going value, in which is merged good will, franchise value, efficiency, favorable business arrangements and design; and it also includes other elements, such as leases, easements, water rights, traffic and operating agreements, strategic location and advantages, and other privileges.

CHAPTER I.

INTRODUCTION.

The Special Committee of seven, appointed by the Board of Direction in September, 1911, to Formulate Principles and Methods for the Valuation of Railroad Property and Other Public Utilities, presented to the Board, early in December, 1913, a Progress Report on the subject of Valuation for the Purpose of Rate-Making.

One member of the Committee was unable to take any part in its deliberations, and consequently did not wish his name attached to the report, which was signed by all the remaining members, consisting of Frederic P. Stearns, *Chairman,* Leonard Metcalf, *Secretary,* Thomas H. Johnson, Alfred Noble, William G. Raymond, and Jonathan P. Snow.

The report was presented at the Annual Meeting of the Society on January 21st, 1914, and, after a brief discussion, the following resolutions were adopted: First, a resolution offered by the Chairman, as follows:

"*Resolved,* That the Progress Report of this Committee, together with all discussion thereon up to September 1st, 1914, or to such later date as the Board of Direction may fix, be referred back to the Committee for further consideration; and that in the meantime the Board of Direction be requested to assign a date for the written and oral discussion on the subject."

Second, a resolution offered by a member:

"That inasmuch as each member of the Society has a copy of that report, that it be not published in the *Proceedings* until the final report of the Committee is issued."

A special meeting for the discussion of the Progress Report of the Committee was held on March 11th, 1914, when the report was discussed by ten members of the Society, and the meeting was adjourned until April 2d, 1914, when it was again discussed in the afternoon and evening by fourteen members of the Society. The total number of written discussions to the present time is sixty-three, covering 340 printed pages of the *Proceedings.*

The Committee suffered a great loss by the death of two of its members: Thomas H. Johnson on April 16th, 1914, and Alfred Noble on April 19th, 1914. To fill the vacancies thus created, and a further vacancy caused by the wish of Henry M. Byllesby not to remain on the Committee, the Board of Direction on May 6th, 1914, appointed to the Committee Charles S. Churchill, William J. Wilgus, and Henry E. Riggs.

Several of those discussing the Progress Report contended that the Committee, in making a report on Valuation for the Purpose of Rate-Making, should have omitted railroads from its discussion, principally on the ground that railroads are competitive, and that their rates are to a large extent interdependent and must be fixed in accordance with these conditions. Some have gone so far as to infer that it was the aim of the Committee to suggest methods for determining individual rates to be included in a tariff, although there was no suggestion of this kind in the Progress Report, which dealt only with returns as a whole; that is, with the aggregate sum to be earned by means of the rates.

The Committee recognizes fully that an engineering valuation of the property of a public utility is only an element in fixing rates, and that this is especially so in the case of railroads and other competitive public utilities. It agrees with the view as to railway rates, expressed by Judge Prouty in his address to the United States Chamber of Commerce on February 11th, 1914, when he says:

"The rates of public utilities are at the present day usually fixed by commissions, both state and federal. It is perhaps the natural inference that when the value of the property has been determined and the rate of return fixed the work of the commission in establishing the charge of the public utility is comparatively easy. It is only necessary to multiply the value by the rate and to allow a charge which will yield that income.

"And this, with some important qualifications, is true as to certain kinds of public utilities. Take, for instance, a water plant or a gas plant. This serves a single community. As a rule it meets no competition in that service. The amount of its business is known or can be forecast with reasonable accuracy. Even matters of depreciation and such like have come to be pretty accurately understood. It is possible, therefore, to fix with some confidence the rates of such a utility when the value of the investment is known.

"With the railroads, however, this is entirely different for the reason that it seldom happens that a single railroad can be considered by itself. The greater part of the business of the railways of the United States is subject to competitive conditions of one sort and another which are largely controlling so that the rates of one are necessarily bound up with those of another. A moment's thought will show the extent to which this is true."

Also:

"* * * the railroads of this country are so bound up together that their rates are largely interdependent. It is impossible to shake a single railroad free from every other and fix its charges upon the basis of a fair return upon its fair value as you would in case of a gas or water plant. The rate established for one, of necessity, influences and frequently absolutely determines the rate of all, a fact which must never be forgotten in discussing this subject."

In the same speech, however, he adds:

"While, however, I wish to make it perfectly plain that the problem of establishing railway rates will not be solved by this valuation, I desire to say with even greater emphasis that the problem will be enormously simplified. It can be known with certainty whether the general level of rates is or is not too high, and in establishing the charges to be observed by a single carrier, even in fixing the rate upon a single commodity, it will be of much benefit to know the value of the property involved. Every railroad commissioner will join with me in saying that here is the only solid foundation upon which he can stand; that the determination of these values is indispensable to the just and intelligent administration of his work.

"While this valuation will be of incidental benefit to the investor, while it is essential to the work of the rate-making tribunal, it seems to me that its greatest immediate value is political. The state of the public mind towards our railways is such that this information is absolutely necessary."

Whether or not it is proper to base rates on the so-called "value" of the property is no concern of the Committee. The fact is that in many instances, including cases of railroad rates, the reasonableness of rates has been so determined, and, in making their decisions in disputed cases, the Courts have quite uniformly held that a public utility corporation is entitled to earn a "fair return" on the "fair value" of its property used in the public service.

Whenever the determination of the reasonableness of rates is reached in this way, it is necessary to value the property, and to value it in such a way that justice shall be done to the corporation and to the public. As this use of valuation of public utility properties was and now is prominently in the public mind, it seemed desirable to consider first the methods of valuation for this purpose. Hence, the Progress Report was limited to this field.

There seemed to be a failure to understand completely what the Committee proposed in its Progress Report, and there were those who contended that there could be but one value for any plant operated for gain, no matter what the purpose of the valuation. Further consideration by the Committee leads it to believe that much, if not all, of the misunderstanding is due to the unfortunate multiple meaning of the word value. In its own discussion the Committee has had difficulty in reaching conclusions, due to this cause. In its Progress Report the Committee adopted the current usage of the word value in accordance with the precedent set by Courts, authors, and legislatures. One of the most prominent of the authors of works on valuation has recognized the difficulties attached to the multiple meanings in the current usage of the word, but dismisses the subject with the statement that the substitution of other terms is not without difficulties.

After careful consideration, the Committee has concluded that the general use of a modified terminology would go far toward lessening the opportunity for misunderstanding, and therefore suggests that the use of the word "value" be restricted in general to its ordinary significance as defined by the Standard Dictionary: "The desirability or worth of a thing as compared with the desirability of something else," and has recognized the propriety of the use of other terms than "value" to express the bases on which purchase, rate-making, or the determination of the reasonableness of rates, capitalization, or taxation must rest. (See Glossary under VALUE.)

The Committee adopts this terminology except when it is necessary to use the terms "value" and "fair value" with the meanings attached to them by the Courts, in which case they will be enclosed in quotation marks.

The Committee has attempted in this report to cover the whole subject assigned to it, which requires a very extended report, even when it is limited to the general features of the subject. To cover all questions which arise in connection with valuation would be impracticable in a report by a committee of this Society.

The following preliminary statements may assist to an understanding of the discussions which follow:

1.—Although the report deals with the principles and methods of valuation, it lays stress on the fundamental principles. General methods are indicated, but little attention is given to detailed methods which necessarily vary under different circumstances.

2.—The discussions, unless otherwise stated, are confined to normal properties which are neither overbuilt, inadequate, nor improperly located.

3.—It is the view of the Committee that valuation should have its foundation in fact, and that the results obtained should be those which will be fair to the parties affected.

4.—The interdependence of methods of valuation and of regulation of public service properties must be recognized. Different methods of regulation may be adopted, which, taken in connection with the appropriate methods of valuation and consistently followed, will be fair to the parties affected. It is not, however, immaterial which of the fair methods are adopted, because one may be more closely in accordance with the law as defined by the Courts than another, and hence may be more capable of being carried out effectively.

5.—Where there may be two or more practicable and lawful methods of procedure, it is still desirable to aim toward uniformity and to select the most approved methods for general use, as this will tend toward simplicity and the avoidance of that confusion of thought and action which occurs when such uniformity does not exist. The methods

recommended by the Committee are those which, all things considered, are in its judgment most desirable for general use.

6.—The various elements which enter into the valuation of a property are frequently interdependent, and equitable results can be obtained only by a recognition of this fact.

7.—As indicated by the preceding paragraphs, a sharp distinction should be made between what may be done now under present laws and what may be done under future legislation and continuous commission control. The recommendations applying to present conditions should not be confused with those which can become practicable only with such legislation and control.

8.—The Committee has devoted the major portion of this report to a consideration of principles and methods which should govern in the valuation of the physical property plus development expense, or, in other words, what it has cost or would cost to create the property and to create the business. The valuation so determined does not cover all the elements of value which should receive consideration from the Courts and the various regulating bodies; therefore, a portion of the report is devoted to a discussion of intangible values and to other matters which may in many cases have an important bearing in the final determination of "value".

9.—Until the science of valuation and the adoption of sound accounting methods have advanced much further than at the present time, it is probable that different methods will have to be used in different cases to produce fair results, and special cases will always continue to arise which require methods adapted to them. The aim, however, should be toward uniformity.

10.—In questions relating to valuation, interest is an important item which should always be considered, and when interest is mentioned in this report it means interest compounded annually.

The valuation of public utilities has obtained special importance in recent years, and most of the literature relating to this subject has been issued within the last sixteen years. The principles and methods involved are now being carefully considered by many public service commissions and the Courts, as well as by engineers, lawyers, and committees of various societies having to do with public utilities. The subject is still in the developmental stage. Until recently, there were no engineering or legal works devoted exclusively to the valuation of public service properties, but since 1911 several important and valuable books on this subject have been published.*

* See "Valuation of Public Service Corporations," by Robert H. Whitten, New York, 1912 and 1914, a comprehensive work in two volumes in legal form, which contains a discussion of the various principles involved in the valuation of the property of public service corporations, and is replete with extended quotations from the opinions of the Courts; also, the following: "Valuation of Public Utility Properties," New York, 1912, and "Value for Rate-Making," New York, 1916, by Henry Floy; "Public

The Committee, in preparing this report, has carefully considered the views expressed in these recent works and in the many written discussions on the Progress Report.

Utilities, Their Cost New and Depreciation," New York, 1913, and "Public Utilities, Their Fair Present Value and Return," New York, 1915, by Hammond V. Hayes; "Principles of Depreciation," New York, 1915, by Earl A. Saliers; and "Public Utility Rates," New York, 1916, by Harry Barker.

See also Bibliography to July 16th, 1913, containing 61 pages, prepared in the Library of the American Society of Civil Engineers, under the direction of the Secretary, at the request of the Committee, *Transactions*, Am. Soc. C. E., Vol. LXXVI, December, 1913, p. 2133. This bibliography, together with an additional 72 pages, bringing it up to December 23d, 1915, has been published by the American Electric Railway Association.

CHAPTER II.

FUNDAMENTAL PRINCIPLES OF VALUATION.

A fundamental principle of primary importance is that a valuation shall be made so that it will be fair to all parties affected.

So long as it is desired that public service corporations and not government shall provide the utilities required by the public, it will be necessary, in the exercise of public regulation, to use principles and methods of valuation which, when properly applied, will attract the capital necessary for building new properties, for extending old ones, and for rendering satisfactory service.

Under normal conditions, the investor is induced to create new property by the prospect of obtaining a fair return on the amount of his investment*, and such investment is a fair basis for valuing such new property, but is not necessarily the "value".

Not many years ago, it was very common to value public service property by capitalizing the net earnings, and though the sum thus obtained may be a proper element for consideration under some conditions in the valuation of a property, it is manifestly not a proper basis on which to predicate reasonable returns.

The fundamental principles involved in the valuation of a new property are necessarily different in some respects from those involved in the valuation of an old one, because a new property, which has not begun to earn or to have the value of its parts affected by appreciation or depreciation, stands in a different position from an old one which has been in operation and earning for many years, and has many parts which may have appreciated or depreciated in value. Moreover, in the case of an old property, valuable property or rights may have been acquired or lost, without the payment or receipt of money therefor, as a result of time or through the failure of the public or the owner of the property to assert their authority. Property or rights so gained or lost affect the valuation materially, and a failure to recognize them would be inequitable to the present owners of the property and to the public.

A more extended statement will be given of the fundamental principles involved in the valuation for various purposes of these three classes of property, namely:

- New properties;
- Old properties under commission control from their inception;
- Old properties which have not been subject to continuous regulation.

* The word, as used here, is intended to mean the reasonable and proper investment for creating the property, and not a reckless or improvident investment.

Valuation of New Properties.

If a new property, just ready for operation, is to be valued in connection with the determination of fair return, then, because working capital will be required, unfinished work must be completed, and development expense incurred, a reasonable and proper basis for what the Courts have called "fair value" is the actual investment in the property devoted to public use plus an estimated sum for working capital, final completion, and development expense, the word "investment" being defined, as in this report, to include not only the outlay of money but also the money value of services and other considerations involved. Such a basis is the most rational one to use in this connection, because a fair return on such a sum, would be a fair return on the investment, and this is what is needed to attract capital to such properties.

If the same property, just ready for operation, is to be valued for public purchase or in connection with condemnation proceedings by a public body, such as a municipality, the public purchase base of a successfully constructed property should be the actual cost, including the money value of services and other considerations involved.

A valuation of the same new property for capitalization should be determined in the same way as the return base, except that all parts of the property, whether devoted to the public use or not, should be included.

A valuation for taxation of a public service property, whether new or old, must accord with the laws of the State in which it is situated, whether or not the laws are equitable, and, where not governed by such laws, should, to make it equitable, be fixed at a sum consistent with the valuation of other property for taxation.

Valuation of Old Properties Under Commission Control from Their Inception.

Some of the basic principles involved in the valuation of old properties can be discussed best by taking a hypothetical case of a normal, well-established property, operating without competition and under commission control as to rates, methods of accounting, etc., from its inception. It is assumed that such a commission would have acted throughout the life of the property in accordance with the basic principles which should govern in such a case. Some of these are:

(*a*) The owner of the property is entitled to reimbursement through the earnings for all current expenses for operating the property and maintaining in good condition the units of which it is composed, including the amounts paid for taxes.

(*b*) The owner of the property is entitled to an allowance sufficient to provide for the net depreciation in the value of all units of physical

property, whether resulting from decay, wear and tear, or other causes, the amount of such depreciation allowance to be sufficient to pay for all such property units by the time they cease to have value.

(*c*) The owner of the property is entitled to a fair return on a "fair value" of the property, and such return should include, not only the ordinary rate of interest for the use of well-secured capital, but in addition a profit commensurate with the risks incidental to the investment.

(*d*) If, during the early years of operation, before the property is tuned up and the business developed, it is impracticable, as generally is the case, to earn the current expenses (*a*), a suitable depreciation allowance (*b*), and a fair return (*c*), the owner of the property should be compensated in some way for the loss during the early years.

The first of these basic principles (*a*) is universally recognized.

The second (*b*) does not define whether the depreciation allowance shall be annual or otherwise, but the decision of the United States Supreme Court in the Knoxville case supports the equitable principle that the allowance for depreciation should be earned annually and should be of sufficient size to keep the investment intact. A portion of the decision is as follows:

"* * * the company is entitled to earn a sufficient sum annually to provide, not only for current repairs, but for making good the depreciation and replacing the parts of the property when they come to the end of their life. The company is not bound to see its property gradually waste, without making provision out of earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that, at the end of any given term of years, the original investment remains as it was at the beginning."

The third basic principle (*c*) is applicable to normal properties and especially to those not subject to competition, and is in accordance with the general view which has been expressed by the United States Supreme Court for many years, namely, that the owner of a property is entitled to a fair return on the "fair value" of the property.

The fourth basic principle (*d*) can be applied in practice either by increasing the "fair value" of the property by the sum of the deficiency of earnings in the early years, with interest, or by allowing higher rates of return in subsequent years to offset the early deficiency. This subject is further discussed under the head of "Development Expense".

Valuation of Old Properties Which have not been Subject to Continuous Regulation.

The basic principles (*a*), (*b*), (*c*), and (*d*), given on the preceding pages, are important in connection with old properties not subject to

continuous regulation, but there is another basic principle already referred to, relating to such property, which in many cases makes the sum representing the sacrifice by the owner an inequitable basis of "fair value". This is:

(*e*) Valuable property or rights may have been acquired or lost by the owner of a public service property, as a result of time or through the failure of the public or the owner to assert their authority.

A failure to recognize such property or rights in a valuation at the present time would be unfair to the present owner or owners of the property or to the public.

The basic principle (*e*) may apply to many features of an old public service property, but two illustrations will indicate what is intended.

Years ago, in the absence of restrictions on rates, a public service corporation may have had very large earnings, and, after paying out adequate dividends, may have had a large surplus, which it expended in increasing and improving its property. Such action was then regarded as commendable. If the public for many years has neglected to exercise its right to regulate rates, it is only just and equitable that the increase and improvement in the property thus created should be recognized, and that the present-day owners should not be penalized for this neglect.

As an instance of a loss by the owner of an old property, he may long ago have neglected to charge rates sufficient to maintain his investment intact, with a resulting diminution in the value of his property. The public, many years afterward, could not be expected to make good the deficiency of former years. This is the view taken by the United States Supreme Court in the Knoxville case, where it states:

"If, however, a company failed to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purpose of earning a return cannot be enhanced by a consideration of the errors in management which have been committed in the past."

The foregoing discussion is based chiefly on grounds of equity, but it is also true that the Courts recognize as a general rule that it is the present value of property which should be used, and not its cost.

Where the sum representing the sacrifice by the owner cannot be accepted as a basis for valuation, it is necessary to find other bases, and a discussion of these and the fundamental principles in each case will be found in the chapters headed "Original Cost to Date" and "Cost of Reproduction".

CHAPTER III.

PHYSICAL PROPERTY TO BE INCLUDED IN VALUATION.

The physical property to be included in valuation varies in different cases with the use to which the valuation is to be put and the law governing the case. It is desirable to cover the entire property, placing different classes in separate schedules, so that full information may be available to the Court or commission having the final decision as to the property to be included.

The most important questions which arise in making schedules are those which ask whether, and to what extent, property not devoted to the public use, property retired from service, temporary works, donated property, leased property, working capital, and securities owned shall be included. Is it proper to exclude a part of the total value of works on the ground that they have been built of a size in excess of that required for the service? Is the title to a property a controlling feature in determining whether or not it shall be included in the schedule? All these questions will be discussed in this chapter.

Used and Unused Property.

It is the well-established rule of the Courts that when a valuation is made for the purpose of rate regulation, only that property is to be included which is devoted to the public use or is used for the public convenience. In a valuation for capitalization, it is obvious that all the property should be included. In the case of condemnation of a property which is taken over by the public authorities, all the property condemned would be subject to valuation, and according to law every element of its value should be included.

The opinion of the United States Supreme Court with regard to the property to be included in valuation for rate regulation is shown by the following brief quotations from decisions, covering the period from 1898 to 1913:

"The fair value of the property being used by it for the convenience of the public." "What the company is entitled to ask is a fair return on the value of that which it employs for the public convenience." (Smyth *v.* Ames, 169 U. S., 466, March 7th, 1898, page 546.)

"The then value of the property actually used for the purpose of supplying water." (Stanislaus County *v.* San Joaquin and King's River Canal and Irrigation Co., 192 U. S., 201, January 18th, 1904, page 213.)

"The fair value of its property devoted to the public use." "The value of its property actually used for the public." (Willcox *v.* Consolidated Gas Co., 212 U. S., 19, January 4th, 1909, page 50.)

"The basis of calculation is the fair value of the property used for the convenience of the public." (Minnesota Rate Cases: Simpson *et al. v.* Shepard; Same *v.* Kennedy; Same *v.* Shillaber, 230 U. S., 352, June 9th, 1913, page 434.)

In view of these decisions, it is clear that the law does not provide for the inclusion of unused property in a valuation for the purpose of rate-regulation, but there must necessarily be much latitude in the determination of the property to be classed as "used" and "unused". Although a few of the discussions by the Courts indicate a tendency toward the exclusion of all property not "actually used", in cases of doubt both Courts and commissions have in practice favored including rather than excluding property.

Clearly it is a narrow construction of the law to claim, as has sometimes been done, that all property not actively in use at the time of the valuation should be excluded. A broader policy is desirable, both in the interests of the owner of the property and of the public. The property considered to be devoted to the public use, and therefore to be valued, should include, not only that in active use in the every-day operations, but that which is properly and reasonably held in reserve to insure the sufficiency and continuity of the service.

In general, it is not proper to apply any arbitrary rules excluding property temporarily out of use. Railroad equipment may be stored during periods of depression; snow-plows and flangers are in use only a small part of the time, and thousands of other cases might be cited of property not actually in service at the time of the appraisal, but useful, and essential as a part of the equipment of the property. In like manner, the duplicate pumps in a water-works, and reserve power units of all kinds, are essential to the proper operation of the property and necessary in times of emergency, although not actually used any considerable proportion of the time. No rule of valuation which excluded such property could be sustained by sound reasoning, as the very life of the service depends to a large extent on sufficient reserve to tide over emergency or peak of business. Such property should be included in regular schedules.

Recognizing that the erection of manufactories and other buildings, the opening of new streets, the laying out of parks, and the making of other customary improvements in the neighborhood of public utilities, as well as increases in the value of adjoining property, will make the future acquisition of lands for the expanding needs of such public utilities difficult and expensive, if not impossible, it has been customary for public utilities to exercise foresight in the purchase of surplus land at crucial points, and in the opinion of the Committee it is in the interest of both the owner of the property and of the public that such land purchased in good faith and held in reserve for future use

should be included in the valuation, even though portions are for a time not in active use.

The following extract from a decision of the New York Public Service Commission for the Second District, in a rate case, is quoted as an instance of what appears to be a rational treatment of the problem of determining what portion of certain lands should be included as used property (Buffalo Gas Co. *v.* City of Buffalo, 3 P. S. C., N. Y., 2 D., 553, February 4th, 1913, pages 578-579):

"All of the land at the Genesee Street plant should be treated as in the public service. The contention of the city that a certain parcel next to the canal is not in the public service should not be allowed. It is not in fact used at this moment, but it is directly adjacent to the generating plant of the company, and with any growth in the business would undoubtedly be needed; and justice and fair dealing do not allow for a moment the quantity of land to be scaled down to the lowest point possible under present circumstances. The company is fairly entitled to a reserve of land of this character at this location * * *.

"At East Ferry Street there are 5½ acres of land. The only use it has in the public service is that of a holder station; 5½ acres for this purpose is not shown by any evidence in the case to be warranted. As a matter of fact, but a portion of this land is used for that purpose; and there is no evidence showing that more will be required for public use within a reasonable time in the future or in fact at any time. An allowance of one-half of this land as being in the public service is liberal to the company.

"At Forest Avenue there are two parcels of land separated by the tracks of the New York Central railroad. The smaller tract is rented for and used as a coal yard, and has no connection whatever with the public service. A considerable portion of the larger tract next to the water is not in fact used in the public service at the present time. The holder and engine-house are situated at one end of the lot, and some small cheap buildings at the other end which are not used for gas purposes. Owing to connection with the street, location of piping, etc., it is believed that it may not be unreasonable to treat the whole tract as being in the public service."

Although the Committee believes that the law relating to used and unused property should be interpreted liberally, as above indicated, it recognizes that, were it the policy to value all land which the owners of a public utility might purchase, on the ground that it would be needed for future use, such policy might lead to speculation in land to be held for a time at the expense of the public and subsequently sold at a profit, without having served it.

A very narrow view is sometimes taken on the area of land to be included in a valuation for rate regulation, as for instance in the case of a recent railroad rate investigation where it was claimed that there should be excluded from the valuation (*a*) all lands owned in terminals and large cities not actually in present use and covered with tracks,

buildings, or company materials, and (*b*) all portions of the right of way not actually included within the slopes of cuts or fills.

The width of a railroad right of way is determined by the depth of excavations or embankments, the necessity of securing materials for forming the banks, the need of providing room for the operations of contractors, as well as by consideration of the necessities of operation.

Another case called to the attention of the Committee is an objection to the inclusion of lots in a city making a right of way 225 ft. in width, while the present use of the property is to support a double-track bridge 65 ft. from the top of rail to ground surface, the present structure covering the central 50 ft. In this case the entire strip was amply justified on three grounds: (1) that it was all needed for the construction and maintenance of the present large timber structures and that any less would give insufficient room; (2) that the land owned was barely sufficient to support an earth embankment if that form of permanent structure should finally be determined upon; and (3) that the land was necessary for the protection of its existing structure from encroachment of buildings which would create a fire hazard.

It is the opinion of the Committee that, in a valuation for the purpose of rate regulation, there should be included, not only the lands actively in use and covered by the construction, but such additional area as is necessary to permit the economical construction of the works, to safeguard the property and protect it from such encroachments as might interfere with its operation or create an extra hazard and to provide for permanent in place of temporary construction. Good business judgment in the acquisition of land frequently requires the purchase of a whole parcel of land where the greater part of the parcel is required for the purposes of the utility. All the land thus acquired should be included in a valuation.

If a 100-ft. strip of land constituted a proper width for constructing a certain single-track railroad and permitted the construction operations to be handled economically and properly, no part of that right of way should be excluded on the ground that the embankments only occupied space equivalent to 41 ft. average width.

Equally important is the question of inclusion or exclusion in valuation for rate regulation of lands held in reserve for future extensions.

In very many, if not most, cases where this question is raised it will be found that a tract of land has been acquired sufficient to provide a suitable site for the proposed plant and to provide for such extensions as are reasonably likely to be made in the near future. It is poor business judgment to build a gas plant, an

electric plant, a railroad shop yard, or other like property, on land just sufficient to hold the buildings and other improvements immediately necessary, without reasonable provision for expansion. The history of all properties that have been built in response to reasonable demand for their services has been a history of growth, development, and expansion. Good business policy would provide for this expansion so far as it can be reasonably anticipated, and all property should be included which is not in excess of a reasonable amount for development of the business over a reasonable period of time in advance of the valuation. Such a determination is not a matter of pure speculation. An investigation into the history of the growth, expansion of business, and expansion of physical property of the company, together with a consideration of existing conditions at each site, should easily determine the reasonableness or unreasonableness of the inclusion.

A very mooted question as to the inclusion of land is found in the case of a company which has bought such property, disconnected from existing works, for future use and development. Often many large holdings are acquired some time in advance of development, at prices much lower than would prevail if bought when the need was pressing and the transaction forced. The general policy of the Courts appears to have been to exclude such holdings in cases relating to rate regulation, unless it was apparent that the property was to be used in the near future.

While the rulings of the Court in regard to the exclusion of such reserve properties, or properties which have not yet come into use, may be justified on the ground that the company may defer its purchase unless it is willing to take the risk that the advance in value will furnish sufficient compensation for holding the property, and while it is true that there are cases in which to include all such properties would lead to abuse, the Committee is of the opinion that there are other cases in which it is very desirable, in the interests of economy and efficiency, that corporations should anticipate the future needs of the service, and that the reserve properties held to meet such future needs should be included in valuation. Instances might be: a distributing reservoir site on the top of a hill, purchased before the hill property is sub-divided into streets and house lots; a dock site on a deep-water harbor for the future use of a railroad; and water rights acquired when they can be obtained at small cost, lest by reason of later developments the company may have to pay heavy consequential damages or substantially monopoly prices for them, or even be unable to obtain them if they have been appropriated by others, the last instance being particularly applicable to the semi-arid and arid regions in the Western and Southwestern United States.

The foregoing views may be less applicable when the valuation of the land purchased for future use is based on the reproduction cost, than when based on original cost, because, if the public is required to pay an increased rate on account of the inclusion of land which is not used, and the increase in the value of land as shown by the difference between reproduction and original cost inures to the company, an inequitable result may be reached.

In the actual work of making a valuation, there are many cases in which there would be no difficulty in reaching a decision as to whether or not a given property should be classed as a part of that used for the convenience of the public. For instance, property used for the commercial mining of coal, although owned by a railroad company, obviously should not be included in a valuation of the property of that company devoted to the public use, but there are other cases in which it is more difficult to decide. Among these may be mentioned office buildings owned by public service companies, which are rented wholly or in part to the public, property temporarily leased to others, pending its active use in the service of the public, and hotels and parks owned by railroad companies. Matters of this kind generally have to be settled by a consideration of the specific cases, on the basis that properties which are a part of the operating plant of the company or are being used for the convenience or benefit of the public should be included. When so included, the income arising from the operation of these properties should be duly credited.

Retired or Discarded Property.

Closely allied with, and in fact a part of, the unused property is that which has been used by a public service company and has been retired or discarded prior to the time of the valuation.

Under the rulings of the Supreme Court, and in accordance with many rulings of other Courts and of commissions, such property would be excluded from a valuation. There are cases in which such rulings seem to be opposed to fair dealing to the owner of the property abandoned. Instances of this kind may be found where a telephone or electric light company is suddenly ordered to remove all overhead wires and place them underground, before the company has had an opportunity to charge off the cost of the overhead wires.

Under public regulation at the present time, due account is sometimes taken of that part of the cost of the discarded property which has not been charged off, and the public service company, instead of being required to charge the remaining cost of the discarded property at once to operating expense, is permitted to charge it to a suspense account for the purpose of distributing the loss to the operating expense of a succeeding period of years.

The Interstate Commerce Commission, in its uniform system of accounts for telephone companies, referring to such losses, states ("Uniform System of Accounts for Telephone Companies", First Issue, effective January 1st, 1913, page 68):

"Losses of this sort may be due to the requirement by lawful authority or public necessity of improvements involving the abandonment of a considerable portion of plant and equipment before it has attained its normal life in service, or to an extraordinary casualty entirely unforeseen and unprovided for. The original cost of the property so abandoned or destroyed should be credited to the fixed capital accounts in which it was carried, and such portion of the cost as may be authorized by the Commission may be charged to the suspense account, the remainder of the cost, less any salvage, being charged out as elsewhere provided in case of retirements of property. The suspense account so raised should be credited and account No. 609, 'Extraordinary Depreciation', debited monthly with such an amount as will, through its regular application, amortize the amount of the loss at the end of the period designated."

Similar provisions occur in the systems of accounts for other carriers.

In a few instances public service commissions have permitted the inclusion of discarded property in the valuation for a term of years. As an instance, a decision by the California Railroad Commission in a rate case is quoted (Solari *v.* Tuolumne County Electric Power and Light Co., 3 Cal. R. C. R., July 29th, 1913, pages 1051-1052). The valuation was that of an electric plant.

"It seems fair, however, to permit the defendant during each of the ensuing ten years to collect rates high enough to permit it to charge off such sum on its books that by the end of the ten years the principal so charged off, together with the interest, shall have amounted to the entire value of the line at the present time. I believe that it will be very liberal on the part of the rate-fixing authorities to permit this to be done."

Where plant units have been worn out in service and definitely abandoned, or by reason of the reconstruction of property, parts have been abandoned, and are not only unused but not likely again to be used, such units and parts should appear either in a separate schedule of retired or discarded property, or such full statement of the conditions should be made as will definitely fix the status of the units or parts.

There is another class of property which, even though out of use, should not be excluded from a valuation on the ground that it is retired or discarded property. This includes the temporary works required for the construction of the permanent items of physical property, as, for instance, the temporary falseworks used to support a bridge during its construction, the coffer-dam required to keep the

site of a dam or a bridge pier free from water, or material and labor of preliminary track surfacing required for the protection of rails from injury under construction traffic prior to the commencement and completion of permanent ballasting. Although such temporary works are discarded after the completion of the permanent works, their cost is clearly a part of the cost of the permanent works, and is properly includible when determining unit prices.

Similarly, the cost of temporary works which are necessarily built in connection with the construction of permanent works, as, for instance, the cost of a pile bridge built in advance of the completion of a permanent bridge for the purpose of expeditious and economic construction, should be included in the cost of the permanent bridge.

In accordance with the same general principle, it seems proper to include in a valuation the cost of temporary works built to furnish service to the public at an earlier date than it could be furnished by the permanent works. For instance, a temporary water-works pumping station is sometimes provided for use during the construction of a permanent pumping station. Such works may be advantageous to the public as well as to the owner of the public utility, and their cost may be regarded as a part of the cost of construction, although due allowance should be made for receipts from operation.

Excessive Size or Capacity.

Somewhat allied to the question of used and unused property is that of excessive size or capacity. It is sometimes claimed that the public should not be required to pay rates on works having a size or capacity in excess of that required for the purposes of the community served. Rulings on this feature of valuation have been made by the Courts and commissions in several instances.

Judge Savage of the Maine Supreme Court used this illustration (Brunswick and Topsham Water District *v.* Maine Water Co., 99 Maine, 371, Dec. 14th, 1904):

"Suppose that a five-hundred horse-power engine was used for pumping when a one-hundred horse-power engine would do as well. As property to be fairly valued, the larger engine might be more valuable than the smaller one, yet it could not be said that it would be reasonable to compel the public to pay rates based upon the value of the unnecessarily expensive engine."

Judge Pitney, of the New Jersey Chancery Court, diminished the valuation of a water plant by nearly $130 000 out of a total of $1 400 000, on the ground that a 36-in. main was used where a 30-in. main would have been sufficient, and because a dam was made of excessive width for present purposes in order that it might be raised subsequently. (Long Branch Commission *v.* Tintern Manor Water Co., 70 N. J. Eq., 71, November, 1905.)

In most of the commission decisions stress is laid on the necessity of providing adequately for future needs in order that satisfactory service may be furnished continuously, and it is stated that it is not desirable in the general interest of consumers to discourage a reasonably liberal provision for the future.

The Canada Board of Railway Commissioners, in the application of the City of Montreal for the reduction of telephone rates, made the following statement, October 28th, 1912:

"There is no question that preparation for future needs is one of the incidents of the proper management of a public utility corporation. If it is to allow demands for service to pile up and then make an expansion only after the urgency is sufficiently great, the public will be subjected to the disadvantage of delay in obtaining service, and at the same time the piecemeal method of construction this will necessitate will undoubtedly add to the cost of the plant. A comprehensive system of preparation for future needs must be followed if there is to be proper expansion. Undoubtedly this will normally lessen the cost of construction to the company. It is also of advantage to the public using telephone service because it gives a decreased basis on which earnings are to be obtained."

In the case of the Des Moines Water Co. *v.* City of Des Moines, the Master, in his report of September 16th, 1910, says:

"* * * the company has the right to anticipate the growth of its business and to be allowed a proper return on a plant of sufficient capacity for such growth."

The Massachusetts Gas and Electric Light Commission, in the Haverhill gas rate case, decided December 31st, 1912, made this statement:

"The Board can not, in the general interest of consumers, discourage the reasonably liberal provision for the future which this company seems to have made."

It is the judgment of the Committee that there should not be a reduction in the valuation on account of excessive size or capacity, except when the excess is so great as to be clearly unreasonable and is the result of not using proper foresight. The opinions of engineers and others engaged in building public service property differ materially as to the length of time for which it is economical and proper to make provision under the different circumstances, and property built with reasonable foresight should not have its value diminished because expectations have not been fulfilled by subsequent developments.

If the opposite course is pursued, corporations may be deterred from making wise provision for the future, thereby increasing the hazard of the investor, probably increasing the ultimate cost by reason of premature retirement, duplication, or piecemeal construction, and hence ultimately increasing the cost of service to the public.

Donated Property.

The Committee believes that land or other property which has been voluntarily donated by the public or by private parties to a railroad or other public utility should be included when determining the reproduction cost, on the same basis as land and property otherwise acquired.

It is especially true that property donated many years ago should be so included, because the company which has held such property for a long term of years, with the acquiescence of the public, has acquired full rights therein, even if it did not have them originally. Such donations were generally made because companies could not profitably furnish a demanded service without such assistance. The donations were necessary to prevent the proposed project from becoming a "losing venture".

There are some instances in which a company has the title to a given property which should not be included in the reproduction cost, and, conversely, other instances in which a company has no title to a given property which should be included in such cost. This subject is discussed on subsequent pages of this chapter, under the heading "Title to Property not Conclusive".

Leased Property.

In the case of leased property, either the property itself or the lease should be valued, as circumstances may dictate.

When a valuation is made for the purpose of rate regulation, it is usually customary and proper to include in it property owned or leased for long-term periods and used for the convenience of the public, although the valuations of the owned and leased property should be kept separate for the information of the Court or commission. Short-term leases may be given a positive or negative value, according to whether they represent prospective profit or loss.

When a valuation is made for the purpose of capitalization, property leased to and not owned by the corporation whose property is being valued should be excluded, although there may be exceptions to this rule in the case of leases which for any reason are practically equivalent to ownership.

When a valuation is made as a basis for selling the property of the operating company, the value assigned to leaseholds should depend on the duration, character of control, and advantages or disadvantages accruing to the lessee by reason thereof.

The foregoing statements are chiefly applicable to leases made between public service corporations, and may not apply to the many instances in which minor leases are made between a public service corporation and private parties.

Title to Property Not Conclusive.

When a valuation of a public service property is made, it is frequently necessary, in order to be fair to all parties interested, to depart from the usual rules relating to ordinary private property, and to include in the valuation more or less property situated on land to which the owner of the public utility has no title, and, on the other hand, to exclude property situated on land to which he has a title.

The proper general rule, subject to exceptions, appears to be that the owner of a public utility is entitled to have included in the valuation of his property all those works for which he has been required by law or necessity to pay the cost, including in this class also property voluntarily donated, and that there should be excluded all those works for which other public service companies, the public or the users have been required by law or necessity to pay the cost.

For instance, it would be unfair to require a railroad company, as a part of the work of abolishing grade crossings, to raise highways in order to furnish suitable approaches to an overhead bridge, and to exclude the embankments thus formed from a schedule of the company property to be valued, on the ground that the company did not have the title to the land on which they were located, or for the same reason to exclude from the schedule in the valuation of street railway property the pavements which the company may have been required to lay in connection with its tracks.

Similarly, in valuing a water or gas property, it would be unfair to include in the schedule those service pipes from the mains to the street line that have been paid for and are maintained by the consumers of the water or gas, unless contractual obligations shall determine otherwise.

The pavements over the mains laid by gas and water companies furnish further instances of property to which the companies have no title, but it is generally conceded that the companies are entitled to have included in an estimated cost of reproduction the cost of removing and replacing such pavements as were actually removed and replaced by them when laying the mains.

The propriety of the inclusion or exclusion of the cost of removing and replacing the paving over mains not actually removed and replaced, is discussed in the chapter on reproduction cost. There is, however, a difference of opinion as to whether the cost of removing and replacing pavements laid at the expense of the public after the mains were in place should be so included. In accordance with the rule above stated, they should not be included, though upon a strict interpretation of reproduction under present conditions, the pavements would have to be cut, and if they can be shown in fact to increase the value of the pipe system, and the property as a whole,

this increase in value may be considered. In the most recent decision of the U. S. Supreme Court, however, the Court has held that they did not in fact increase value in the case under review.

The more recent and important Court and commission decisions exclude from "fair value" those pavements and other items laid or constructed without expense to the company.

In 1907, the decision of District Judge Hough, of the Federal Court, in the Consolidated Gas Co. case (Consolidated Gas Co. *v.* City of New York, 157 Fed., 849, December 20th, 1907), included in "fair value" the increased construction expense of pipe systems over which pavements had been placed at the expense of the city. On appeal, the United States Supreme Court (Willcox *v.* Consolidated Gas Co., 212 U. S., 19, January 4th, 1909) did not take up the question of the inclusion of pavements, but concurred with the Court below to this extent:

"And we concur with the court below in holding that the value of the property is to be determined as of the time when the inquiry is made regarding the rates. If the property, which legally enters into the consideration of the question of rates, has increased in value since it was acquired, the company is entitled to the benefit of such increase. This is, at any rate, the general rule."

In 1912, District Judge McPherson, of the Federal Court, in the case of the Des Moines Gas Co. *v.* City of Des Moines (199 Fed., 204, August 21st, 1912), supported the exclusion by the Master of the reproduction cost of pavements laid at the expense of the city, thus taking a position diametrically opposite that taken by Judge Hough.

Upon appeal, this case went to the United States Supreme Court (238 U. S., 171, June 14th, 1915), which supported the attitude of the Master and of Judge McPherson regarding the exclusion of pavements laid at the expense of the city. Mr. Justice Day says:

"As to the item of $140 000, which, it is contended, should be added to the valuation, because of the fact that the Master valued the property on the basis of the cost of reproduction new, less depreciation, and it would be necessary in such reproduction to take up and replace pavements on streets which were unpaved when the gas mains were laid, in order to replace the mains, we are of opinion that the court below correctly disposed of this question. These pavements were already in place. It may be conceded that they would require removal at the time when it became necessary to reproduce the plants in this respect. The Master reached the conclusion that the life of the mains would not be enhanced by the necessity of removing the pavements, and that the Company had no right of property in the pavements thus dealt with, and that there was neither justice nor equity in requiring the people who had been at the expense of paving the streets to pay an additional sum for gas because the plant, when put in, would have to be at the expense of taking up and replacing the pavements in building

the same. He held that such added value was wholly theoretical, when no benefit was derived therefrom. We find no error in this disposition of the question."

One of the modern decisions along these lines is that of the Court of Appeals of the State of New York (Kings County Lighting Co., People *ex rel. v.* Willcox, 210 N. Y., 479, March 24th, 1914). The New York Public Service Commission for the First District declined to include in a valuation of the property of the Kings County Lighting Company the pavement over its mains in cases where such pavements were not laid at the expense of the company.

The Appellate Division of the Supreme Court of New York reversed the determination of the Commission. The case was taken to the Court of Appeals, which reversed the action of the Appellate Division and sustained the ruling of the Commission. Judge Miller says (at pages 494-495):

"In determining the cost of reproduction, the Commission allowed $12 717 as the cost of restoring the pavement as it existed when the mains and service pipes were laid in the streets. The relator claimed an allowance of at least $200 000 for the cost of restoring pavements subsequently laid, on the theory that the cost would have to be incurred if the mains were to be laid to-day. But the new pavements in fact added nothing to the property of the relator. Its mains were as serviceable and intrinsically as valuable before as after the new pavements were laid. The controlling considerations under the preceding point also determine this. The rights of the public are not to be ignored. The question has a double aspect. What will be fair to the public as well as to the relator? (Smyth *v.* Ames, *supra.*) Should the public pay more for gas simply because improved pavements have been laid at public expense? It is no answer to say that the new expensive pavements suggest improved conditions which, though adding to the value of the plant, will not, by reason of the greater consumption, add to the expense per thousand feet of the gas consumed. The public are entitled to the benefit of the improved conditions, if thereby the relator is enabled to supply gas at a less rate. The relator is entitled to a fair return on its investment, not on improvements made at public expense. It is said that the mains will have to be relaid. So will the new pavements, and much oftener. Both might possibly be relaid at the same time. The case is not at all parallel to the so-called unearned increment of land. That the company owns. It does not own the pavements, and the laying of them does not add to its investment or increase the cost to it of producing gas. The cost of reproduction less accrued depreciation rule seems to be the one generally employed in rate cases. But it is merely a rule of convenience and must be applied with reason. On the one hand, it should not be so applied as to deprive the corporation of a fair return at all times on the reasonable, proper and necessary investment made by it to serve the public, and on the other hand it should not be so applied as to give the corporation a return on improvements made at public expense which in no way increase the cost to it of performing that service.

"The Appellate Division felt bound by the decision of the United States Circuit Court in the Consolidated Gas Case (157 Fed. Rep., 849), and it is true that such an allowance was made in that case. But the United States Supreme Court held in that case (212 U. S., 19) that the rate established was not confiscatory, and did not pass on the propriety of that allowance. What was said in the opinion on the subject of present value was merely a general statement having no necessary relation to the question now under consideration."

The more recent decisions of the California, Illinois, Indiana, Maryland, New Jersey, New York, Washington, and Wisconsin Commissions have excluded from "fair value" the cost of pavements laid without expense to the company.

This subject is discussed further under the caption "Shall Present or Original Physical Conditions Govern?" on pages 1761 to 1768.

Under special laws providing for the creation of some public utilities, of which elevated railroads and large storage reservoirs are examples, it is required that the owner of the utility shall pay incidental damages on account of property injured, but of which no part is taken. Such damages are an important factor in the original cost of a property, and a corresponding item should appear in the reproduction cost, irrespective of the fact that the owner of the public utility has no title to the property in question.

Working Capital.

It is customary to include under the term "working capital" the amount of cash, materials and supplies provided for use in the plant but not yet forming a part of it, and other current assets which are essential for the proper maintenance, operation, and administration of a property.

There should be included in a valuation an amount of working capital sufficiently large, not only to meet the usual requirements, but to provide for emergencies.

Securities Owned.

Ordinarily, the valuation of property devoted to public use should not include securities owned or surplus cash not forming a part of working capital, except in instances where such securities and surplus cash are an offset, in whole or in part, for depreciation deducted from the cost of the property. The treatment of such cases is covered in Chapter VI, "Depreciation and Appreciation."

CHAPTER IV.

ORIGINAL COST TO DATE.

The term "original cost to date" is used in the Federal Valuation Act, and appears to have substantially the same meaning as the terms "original cost", "original cost plus improvements", and "actual cost".

In the absence of any generally accepted or well-defined legal meaning of this term, the Committee has defined it as "the cost of the original construction, plus all charges against capital proper, under approved accounting principles, for expenditures incurred thereafter, and minus all proper credits to capital for the cost of property which has been disposed of or otherwise retired".

Under this definition, the original cost to date of a property is the first cost* of the identical property units now in use, including overhead charges. This definition accords with modern methods of accounting, by which the cost of property retired is credited to the fixed capital account† to which it stands charged, or to some corresponding account, and the cost of property, added as a replacement, or otherwise, is debited to the fixed capital account or other corresponding account; it seems, also, to conform more nearly than any other definition with the decisions of the Courts that property which has been retired shall be excluded (excepting its salvage value) when making a valuation.

In the case of properties built by present owners, original cost to date should agree with the book or accounting cost in most respects, if modern methods of accounting have been followed from the beginning, but, even with such properties, correct accounting in accordance with modern practice is rare, and book cost, even when the books have been well kept, may differ greatly from original cost to date, as above defined.

* The definition of cost given by the Committee includes "not only money outlay, but also the money value of services rendered and of other considerations involved".

† In "Uniform System of Accounts for Telephone Companies", as prescribed by the Interstate Commerce Commission, First Issue, Effective January 1, 1913, fixed capital is defined as "property, both tangible and intangible, which is devoted to the accomplishment of the principal purposes of its business", and it "consists of original capital, additions, betterments, and replacements".

Referring to replacements, which it defines as "the substitution of one building, structure, piece of equipment, or machinery for another which it has become necessary to retire, the substitute having substantially no greater capacity than the property replaced", it provides the following method of accounting:

"The cost of the fixed capital retired should be credited to the fixed capital accounts in which it is carried and the cost of the fixed capital installed in place of fixed capital so retired should be charged to the appropriate subaccounts under account No. 101, 'Fixed Capital Installed Since December 31, 1912'."

Under the head "Fixed capital withdrawn or retired", it provides:

"When any tangible fixed capital acquired subsequent to December 31, 1912, is withdrawn or retired from service for any cause the amount at which it stands charged should be credited to the fixed capital account in which it is charged, and such amount, plus the expenses incident to the retirement, less the value of salvage, should be charged to account No. 102, 'Reserve for Accrued Depreciation—Cr.' "

One important difference between book or accounting cost and original cost to date has arisen from a former method of bookkeeping which is still in use for some classes of property, by which, when a plant unit is replaced by an identical unit, no entry is made on the books, and consequently the cost of the original unit is retained and not the cost of the succeeding unit.

For instance, if a pipe costing $20 per ton for material is replaced by one of the same size and weight costing $25 per ton for material, the cost at $20 per ton remains on the books. Similarly, if a plant unit is replaced by one of larger size or heavier weight, the cost of the additional size or weight is entered on the books at the prices existing at the time of the replacement, and added to the cost of the original unit, so that the new unit appears in part at one price and in part at another.

Difficulty in Obtaining Original Cost to Date.

The statement has frequently been made, by those dealing with the valuation of public service properties, that it is not feasible to obtain the original cost to date of most old properties, and this is undoubtedly true in most cases in regard to the older portions of such properties and to the overhead charges. The difficulty, however, has been magnified in some cases by the conception that original cost to date deals with the money paid for original property units which have been replaced, and not with that paid for existing units. In some cases much of the difficulty may be removed under the definition given by the Committee, especially in the case of short-lived property.

As original cost to date, with comparatively few exceptions, is not the book cost of the property but the cost of the existing items, it will be necessary as a rule to make a schedule of the various existing property items, in the same way that one would be made for determining the cost of reproduction; then reference would have to be made to the accounts, to ascertain the unit costs of the items.

It would seem that almost any system of accounts which was correctly kept, even if not based on modern accounting principles, should show the cost of those items which have been purchased in the last 10 to 20 years. The cost of longer-lived items may not appear on the books, or the books for the earlier years may not be available, especially if the properties have changed hands. In such cases, the only way in which the determination of original cost to date could be completed would be by estimating, from the best information which could be obtained, the unit prices existing at the time the property items were constructed or acquired.

In the case of an old property consisting mainly of long-lived items, it is seldom practicable to obtain the original cost to date, except for the additions made in recent years, and if such cost could be obtained it would have little value.

In every case where records of original costs of presently existing items are not to be had, an attempt to determine original cost to date becomes an estimate, the correctness of which will depend on the completeness and accuracy of existing historic data. The result is likely to be less inaccurate in the case of a recently built property than in the case of an old property, but in no case in which estimate must be resorted to can the result properly be called original cost to date.

Schedule.

To ascertain original cost to date, it is necessary, as a rule, that a schedule be made of the various existing property items in the same way that one would be made for determining the cost of reproduction. (See further discussion of "Schedule" on pages 1775 to 1778.)

Exceptional cases, in which a detailed schedule may not be necessary for all parts of a property, include those in which the whole or a part of a property has been built at so late a date that the original units are still in existence, and those other properties of comparatively recent date where the accounting has been such that additions and betterments are charged to the fixed capital account and the cost of property retired has been credited to this or a similar account. However, even in these cases, an inventory may be desirable for the purpose of checking the results obtained from the books. Under the most favorable conditions as to records, it may be necessary to make many adjustments in order to obtain correct results.

Costs—Unit Costs.

In cases where a schedule is necessary, the corresponding costs or unit costs are also necessary in order to complete the inventory. Whether these are the actual costs of units or groups of units, or the unit costs, will depend on the method of bookkeeping which has been used.

There may be many cases in which work which covers many items has been done by a contractor for a lump sum, in which case it may be necessary, in making the schedule, to group the items included in the contract and to place opposite them the total sum paid the contractor, together with all the incidental charges properly attributable to the work.

When practicable, however, it is preferable to keep the items on the schedule separate, or in groups of identical items of the same age,

and to apply unit costs, either given directly in the books or which may be determined from them, including in such costs the direct incidental expenses, such as inspection, freight, carting, storing, laying or placing, etc.

In the case of property units acquired or created long ago, it will be impracticable, as a rule, to obtain the costs or unit costs from the books, and in such cases the ascertainment of the original cost is impossible, and it would have little significance if it could be ascertained.

Overhead Charges.

The expenses to be included in overhead charges are discussed more fully under this head in the succeeding chapter relating to cost of reproduction.

In brief, however, they may be said to consist of the preliminary expenses of promoting, investigating, organizing, and financing, and the incidental expenses during construction, which may be classified under the heads of engineering, general expenses (including the administrative, legal and financial expenses, taxes and insurance), and interest.

When the detailed accounts giving the cost of a property are available, these items should appear in them, but in many cases no account may have been taken of the value of the services of those engaged in promoting and constructing the work, or proper allowance for interest on the capital, or the records may be in such shape as to defy analysis.

Bonds may have been sold at discounts. Under the ruling of the Interstate Commerce Commission, that proportion of discounts and commissions on bonds is to be included in capital which is represented by the proportion of the construction period to the life of the bonds. The remainders of the discounts and commissions are not to be considered as capital, but are to be amortized over the remaining life of the bonds.

The Committee believes that reasonable commissions for selling securities of any kind should be included as a capital charge, but that discounts on bonds over and above such reasonable commissions should be treated as a capital charge only in such proportion as the construction period bears to the life of the bonds, the remainder being amortized over the remaining life of the bonds.

After the construction period has ended and the regular operation of a property has begun, the method of accounting is frequently such that the salaries and expenses of the permanent engineering, administrative, and legal staff are charged wholly to operating expenses, although a part of the time of this staff is devoted to the construction of additions to the property, and should properly be included as a part of

their cost. Similarly, there is frequently a failure to charge to the proper account the interest during the construction of such additions. Adjustments should be made so as to include in the cost of such additions the overhead charges properly attributable to them. On the other hand, there may be occasion, when determining the overhead charges from the book accounts of an old property, to make deductions of such charges as are properly attributable to plant units which have gone out of use.

The statements in the last paragraph may invite the criticism that, if the method of bookkeeping is such that a part of the overhead charges for additions to the property has been placed in operating expenses, it has been paid for by the public and not by the company, and hence should not appear in a valuation of the property. In this matter the Committee makes a distinction between valuation and regulation, and takes the ground that in valuation the total cost of the property should be included, regardless of past methods of bookkeeping. It recognizes, however, that in continuous regulation, including the control of rates by a public service commission, there should be no duplications by charging items to both the capital and the expense accounts.

Development Expense.

The development expense actually incurred in connection with the tuning up and creation of the business of a property should be included as a part of the original cost to date. The subject is fully discussed in Chapter VII.

CHAPTER V.

COST OF REPRODUCTION.

The Theory of Reproduction.

Different Applications of Reproduction in Past Practice.—Cost of Reproduction is defined by the Committee as:

"The estimated cost of reproducing the property without deduction for the loss of value due to age or other causes."

The practice of those engaged in valuation work, from the beginning of such work up to the present time, has varied widely in the matter of determining the cost of reproduction. Some base such cost on existing physical conditions, others on historic conditions, and still others combine the two. Some engineers have included only those physical property units which were actually created in the construction of the property, that is, they have used historic conditions, as to items of cost, with present-day prices for labor and material. Others have used substitute units, or historic prices, or original instead of present methods of work, and still others have used original conditions, original prices, and original methods, in making an estimate of reproduction cost.

This failure of engineers engaged in valuation practice to agree on a uniform conception of reproduction has cast some doubt on the real worth of Cost of Reproduction as one of the measures of value.

The United States Supreme Court, in the Nebraska rate case, states the various matters to be considered in determining value, as follows: (Smyth *v.* Ames, 169 U. S., 466, March 7th, 1898).

"And in order to ascertain that value, the original cost of construction, the amount expended in permanent improvements, the amount and value of its stocks and bonds, the present as compared with the original cost of construction, the probable earning capacity * * * are all matters for consideration and are to be given such weight as may be just and right in each case."

This case has been cited in most valuation cases, and the use of the word "Reproduction" has been very general in subsequent decisions, although it is to be noted it is not used in the decision in Smyth *vs.* Ames. It is clear that the Courts in many cases have recognized the reproduction estimate as one of the most important bases for determining value (Louisville & Nashville R. R. Co. *v.* Railroad Commission of Alabama, 196 Fed., 800 (1912), Hon. Thomas G. Jones, District Judge, N. & M. D., Alabama).

"In reference to the question of value with the view of rate regulation, the most reliable test ordinarily is the cost of reproduction of

the road as it exists. I say 'ordinarily' because there may be instances, which is not the case here, where by reason of paralleling the road by a new road, and diverting its business or from other causes, its value may be far less than what it will cost to reproduce it as it is at the time of the inquiry. The original cost of the road may in some cases reflect light on, or even determine, the present value, as when it is of very recent construction. But ordinarily it is of little assistance in that regard, since many items of value may be donations by the government or by individuals * * * or the road may have been built long before the period of inquiry at greatly less or greatly higher prices than those prevailing at the time of the inquiry. * * * Therefore, while looking at all collateral matters reflecting light on the subject, the court regards reproduction cost as the final test of present value. * * *"

In the Knoxville decision it is stated that:

"The cost of reproduction is one way of ascertaining the present value of a plant."

In this and practically all other cases in recent years, in which the values of old properties were under consideration, the evidence relating to cost which has served as a basis for determining value has been the reproduction cost.

In the case of the Consolidated Gas Co. *vs.* City of New York (157 Fed. Rep., 849, December 20th, 1907), District Judge Hough says:

"The complainant demands a fair return upon the reproduction value thereof, which is the same thing as the present value properly considered. * * * Upon authority, I consider this method of valuation correct. What the court should ascertain is the 'fair value of the property being used'; what complainant 'employs for the public convenience'; the 'present' as compared with 'original cost' (Smyth *vs.* Ames, 169 U. S., at page 547 * * *); and it is also the 'value of the property at the time it is being used' (San Diego Land Co. *vs.* National City, 174 U. S., at page 757 * * *, and see also Stanislaus Co. *vs.* San Joaquin Co., 192 U. S. 201 * * *). It is impossible to observe this continued use of the present tense in these decisions of the highest court without feeling that the actual or reproductive value at the time of inquiry is the first and most important figure to be ascertained."

In this decision value is used in two senses: one, value as the Committee has defined it; and two, as synonymous with cost.

In the Minnesota rate cases, it is stated that:

"The cost of reproduction method is of service in ascertaining the present value of the plant when it is reasonably applied, and when the cost of reproducing the property may be ascertained with a proper degree of certainty. But it does not justify the acceptance of results which depend upon mere conjecture."

This statement follows a discussion of the cost-of-reproduction method as applied to the determination of the value of a right of

way, which consisted largely of terminal property, in which it was held that the cost of reproduction did not give proper results.

This case sounds a note of warning against the use of irrational, or unsound, theories of reproduction, and the use of mere conjecture in making a reproduction estimate.

The Supreme Court has held consistently, in the older cases, that in determining value, original cost under original conditions, and reproduction cost under present conditions, were of the greatest importance, though other considerations, such as selling (market) price of the securities, worth of the service to the consumer, etc., were also of significance. In these older cases the Courts seem to have said that reproduction cost should be determined on the basis of present-day conditions, whether or not the corporation years ago had to take a series of steps involving expense which would not now have to be taken, or whether or not the property was built by piecemeal construction at a necessarily higher cost than would prevail if all built at one time; that "present-day conditions" means present-day prices, present-day methods, and present-day facilities for doing work, and that these should be applied under existing physical conditions.

With the original cost and reproduction figures in hand, determined as outlined above, and with such other information, historic and otherwise, as was available, the Courts have held that valuation should be summed up as a matter of judgment, giving due weight, not only to the results obtained by the application of these different measures, but incidentally to the degree to which the measures are equitably applicable.

The more recent and authoritative decisions of the higher Courts, though they still lean toward defining the cost of reproduction as the cost under present conditions, thus following precedent, also give strong support to the use of historic physical conditions, since, in determining the "fair value" of pipes originally laid in streets having no pavements, but in which pavements were subsequently laid at the expense of the city, they exclude from "fair value" the cost of taking up and replacing the pavements which would be included if one were to base "fair value" on the cost of reproduction under existing conditions. In other words, the sums allowed by the Courts in determining "fair value" are the sums which it would cost to lay the pipes under the physical conditions which existed at the time the pipes were laid. The subject seems to be in a developmental stage in the Courts.

In effect, the Courts in some instances appear to have recognized that a split standard, so to speak, or one which might be defined as reproduction cost under present-day material and labor prices, and historic or past physical conditions, in certain particulars, would do more substantial justice, or be more equitable in the results of its

application, than either the original-cost theory under historic or past conditions on the one hand, or the reproduction-cost theory under present conditions on the other. Under such a standard the owner enjoys the advance in general value standards indicated by the advance in cost of labor and materials, or suffers from the decrease thereof, if these have declined in value, and has recognition given to the conditions under which he made his investment.

May not the question fairly be raised: Has the conception of reproduction, based on present conditions, been a proper conception?

In the opinion of the Committee, this subject is of sufficient importance to justify full discussion of the question: What is the proper conception of cost of reproduction new? In this discussion the Committee will point out some of the difficulties to be met in formulating a rational conception of the problem, will then try to answer four questions, and finally draw its conclusion.

Difficulties to be Met in Formulating a Theory.—The original conception of reproduction undoubtedly grew out of simple conditions, such as would be met in estimating the cost of reproducing a building or a single structure. In this case, the difference between the original cost of the building or structure and the reproduction estimate would be due wholly to changes in prices of labor and materials and the change in methods of doing work. This simplicity of condition does not obtain in the case of a great property, the actual construction of which has extended over many years, many of the plant units of which have been renewed or replaced by larger ones than were originally installed, which has undergone changes and alterations, and the history and records of which have not been kept fully and completely. In such a case the making of a complete estimate of the cost of replacement or reproduction is a very involved undertaking.

When there are added the complexities due to the effect of works built by other companies than the one under investigation, or by municipalities, or to the growth of a community or rearrangement of transportation facilities of a community or section of country, elements are introduced, the proper treatment of which is vital to a reasonable estimate of the cost.

To obtain the reproduction cost of the property, shall it be assumed that all those things must be done that are or were necessary to create a new property in the same location as that of the existing one? It is usually assumed that all other existing properties or conditions affording facilities for, or offering difficulties to, the reconstruction of the property under consideration continue to exist as at present, in so far as they affect the cost of reconstruction; but one cannot forget that the property in question was not built in a day—nor during one construction period.

Nearly all the second, third, and fourth tracks, and side tracks, of steam railroads have actually been built years after the original construction, with certain disadvantages arising from maintaining traffic but with the advantages to be derived from the existence of a well-organized railroad over the entire route. The same thing is true of the construction of many existing structures, such as large buildings, bridges, signal and interlocking systems, and other more recent and modern adjuncts of the railroad systems of to-day.

The actual historic development of railroads has seldom been the springing to life of a new complete up-to-date property, but a growth over a long period of years, each company adding to its track and facilities as the needs of its territory and its business demanded. The same thing is true of water-works, gas, or electric properties, and other utilities in large cities. Under these conditions, it is clear that great care must be exercised in outlining the basis for estimates.

The four main questions to be asked and discussed are:

1.—Shall present or original physical conditions govern?
2.—Shall present or original prices govern?
3.—Shall identical or substitute plant be considered?
4.—What is meant by the word "new", as frequently used in connection with reproduction?

1.—Shall Present or Original Physical Conditions Govern?—A few examples of actual conditions encountered in connection with construction are presented.

Wachusett Reservoir.—This reservoir was built to supply water to the Metropolitan District of Massachusetts. To construct it, it was necessary to acquire land on which there were many buildings, and mills with their water powers. Included in the reservoir site there were also many highways and two railroads. As a substitute for the highways obliterated, others had to be built around the margin of the reservoir, and some were raised above the water level. One of the railroads was relocated for many miles at one side of the reservoir, and another was raised. To make the reservoir a better receptacle for water, the surface soil was stripped from its whole area. One main dam and two subsidiary dams were necessary for holding the water. Incidentally, under special laws, damages had to be paid for real estate which was not acquired, but which was said to be damaged indirectly by the construction of the reservoir.

Kensico Dam.—This dam, of the New York Water-Works, was necessarily located within the limits of an existing reservoir, the water of which could not be drawn down until two new temporary reservoirs had been created farther up stream to maintain the water supply. After these had been completed, the old Kensico Reservoir was drained and the old dam removed. After the completion of the

new Kensico Reservoir, the two temporary dams and reservoirs will be useless.

The AuSable Dams.—By building three dams on the AuSable River in Michigan, the Commonwealth Power Company flooded hundreds of acres to a depth of 40 ft. There was not a house, not a mile of road, no railroads, no damage to property of any kind such as was encountered in the other reservoirs. It was only necessary to acquire the needed lands and flowage and build the dams, without property damages in any appreciable amount.

There are now no buildings, roads, or railroads in the basins of any of these reservoirs, nor does the connection of the Kensico auxiliary reservoirs with the construction of the main dam appear. Therefore, in these three cases, presently existing conditions are not indicative of work done or difficulties encountered in actual construction in the past, nor of what it is fair to assume would be the conditions to be found had the reservoirs not been built. Conditions may be now essentially similar, immediately about these reservoir sites, but it would seem to be unfair for this reason to assume like conditions to govern the estimate of reproduction cost to be used as a basis of "fair value".

The theory of reproduction cost under existing conditions evidently was based on the reproduction of property units which now exist, such as, for instance, buildings, bridges, and other structures and works, and did not take into account that, in creating public service property, there may be much destruction as well as construction. The destroyed property obviously does not exist, and therefore would not be included in the inventory of property to be valued if the theory of determining the cost of property under existing conditions were followed strictly.

In addition to the destruction of physical property, cited in the foregoing, there may be the destruction of business and resulting damage to surrounding property, all of which may prove to be a large element of cost.

On account of the destruction of business, it became necessary in the case of the Wachusett Reservoir to pay for the resulting loss, not only to those owning the business, but to the workmen who were thrown out of employment, and to the owners of surrounding property not acquired for the reservoir but affected in value by the destruction of the manufacturing and other business in a well-populated valley. It is clear that such business will not exist at the time a reproduction cost is being ascertained, and therefore will not be an element of cost under existing conditions rigidly interpreted. The destruction of the business was properly an important element of cost in the creation of a reservoir at this site, would be reasonably certain to be an element of cost in the production of a reservoir at this site at any date of

estimate, if the existing reservoir had not been built, and therefore should be included as an element of cost of reproducing the reservoir.

Your Committee is of the opinion that all such items of cost, due to damages, destruction of property, purchase of rights, and temporary works, as cited in these illustrations, are clearly proper items to be included in the reproduction estimate when capable of historic proof. It would seem that, in such cases as these, fairness to the owners of the property and to the public would necessitate the use of historic conditions, at least to determine the extent, magnitude, and character of property units created, destroyed, or removed, physical evidence of which passed with the construction of the property itself, and which it may reasonably be assumed it would still be necessary to create, destroy, or remove were the property to be built new at the date of valuation.

Another series of examples may be found in the conditions which existed at the time of construction of certain great railway terminals.

The Pennsylvania Railroad Terminal, New York City.—This structure was pioneer construction. Land was purchased extending in a strip across the greatest city in the country. The property was built up solid with buildings, which were not only purchased, but wrecked, and the entire value thereof thrown away. There was no steam railroad traffic to maintain, but there was consequently no benefit to be derived from the existence of tracks for the removal of earth and construction débris.

The New York Central Terminal, New York City.—This terminal replaced an old structure, which in turn had succeeded others on the same site. The existing plant covers an extensive area, the larger portion of which was originally, with respect to the present undertaking, covered with buildings of all kinds and intersected with streets requiring treatment in various ways, as in the case of the Pennsylvania terminal, but in building this terminal, the company maintained a formerly created traffic without interruption, and though thereby the expense of construction was increased by the cost of temporary structures to provide facilities for its patrons, longer time of construction, and cost due to the hampering of operations by not having the entire site available for working purposes, it is probable that these elements of additional cost were largely offset by the savings that resulted from the utilization of the existing accessorial tracks for the handling of construction materials and the disposition of excavated materials in four-tracking the Hudson and Harlem Divisions.

Except with respect to the value of near-by lands, the present conditions about these two properties are much alike, and, for anything that appears, a reconstruction programme for one would be much like that for the other, under present surrounding conditions, and the offsetting effect of the revenue earned by the New York Central Railroad, against its increased cost due to maintenance of traffic, gives

color to the propriety of making like assumptions for both properties. But it should be remembered that only a part of the property of the New York Central Terminal had to be acquired in modern times. Much of it was acquired years ago, when it was not covered by valuable buildings, and it would seem to be unfair to assume, in a reproduction estimate which is to serve as a basis for "fair value", that all of it would be covered with valuable improvements, to be purchased and wrecked simply because surrounding land is now so covered, or because the property acquired by the Pennsylvania Company was so covered. Without the existence of the railroad, the City would not be the city that it is; it is what it is, partly as the result of the existence of the railroad, therefore it cannot be said that if the railroad had not been built, the surrounding lands, and presumably the site of the terminal, would be covered with the valuable improvements now in evidence. Here again it would seem to be fair to refer to history to determine what was done, and would reasonably be supposed still to be necessary to do, to construct the property new.

One illustration brought to the attention of the Committee is a case of a highway which originally crossed a steam railroad at a very acute angle, making a dangerous crossing to both railroad and public. At its own expense, the railroad acquired land parallel with its own, changed the course of the road for several hundred feet and made a right-angled crossing. It was argued that, "in case of reproduction, all other property remaining as at present", the highway would be in its new location and would not have to be reproduced. On this basis, many items which the owner of a railroad or other public utility was compelled to pay for might be cut out of an appraisal. But the highway would be in its original place were it not for the act of the railroad, and would have to be moved by any railroad, building presently, if the existing road had not been built; the evidence of the necessity, however, having been destroyed in the doing. The cost was a proper cost, capable of historic proof; and the Committee believes that it should be included as a cost in the estimate of reproduction.

A certain railroad was built through a heavily forested section of country, largely to develop the lumber industry in that section. The land was worth, and cost the railroad company, upwards of $40 an acre because of its timber value, and the company paid another $40 or $50 an acre, for clearing and grubbing. The timber industry developed, the surrounding lands were cleared and proved to be unattractive for agricultural development, and no large cities built up along the railroad. To-day the timber is gone, there is no clearing to do, and the land has depreciated to a value of $5 or $6 an acre. In this case human progress has taken away from the value of the territory, rather than, as is more usual, added to it. The railroad has

suffered as well, because its local business is largely gone. It has, however, as a part of a large property that has taken it over, developed a good through business. It would seem that all these things must be considered, when determining whether the original conditions for right of way and clearing, capable of proof, shall be used in an estimate of reproduction cost, or on the other hand what would be the present-day cost of acquiring the already cleared right of way. It is manifest that the railroad company contributed to the present condition, by providing the means for removing the lumber. Presumably its promoters should have been able to foresee what the general result of the lumbering operations would be, and should have reimbursed themselves, in the early days of the enterprise, for the possible future loss in value, due to the changed conditions, and in general it must be said that such enterprises assume the hazards of such results of human progress, particularly those to which they themselves contributed largely. Nevertheless this line, while apparently not now needed for the country through which it operates, and which, but for its connection with a greater property, would certainly have to be depreciated in value by at least the diminished cost of reproduction; yet, as a going property, adequately serving the public in its through business, it would seem to be unjust to take away from it all hope of future life as might result from a limitation of its return to "fair return" on a greatly depreciated actual investment.

One element of cost, being typical of a class and easily separable, deserves discussion by itself. This is the cost of removing and replacing paving of streets over and around public utility properties. It is of importance in connection with street railways and all underground conduit lines for gas, electricity, water, or other commodities.

Street railway properties occupying the streets of large cities do so under grants which vary widely in terms as to paving. In every case the burden is on the company to build such a type of construction as will permit that part of the public not depending on the railway company for transportation to enjoy the free and unrestricted use of the street.

A certain street railway company owns a large mileage of track in paved streets. In addition to the not uncommon case of tracks which were laid before the streets were paved, several different cases of complication as to paving are found:

Case 1.—The street railway company built all the track foundations, track superstructures, and pavement.

Case 2.—The street railway company built all the track foundations and superstructures, but the city built the pavement.

Case 3.—The street railway company built the track superstructure, but the city built the track foundations and pavement.

Case 4.—The street railway company built the track foundations and superstructure and took out and rebuilt existing pavements, but subsequently the city repaved the entire street at no expense to the company.

In making an appraisal of this property it will be necessary to define clearly what items shall be included in the reproduction estimate, and to answer, among others, these questions: Shall allowance be made for the removal of paving on all streets, whether they were unpaved or paved when the tracks were built? Shall allowance be made for all track foundations, or shall investigation be made as to what was done by the city, and that part excluded? Shall allowance be made for paving in all streets in which there is paving?

The Committee is of the opinion that in all cases where such questions are at issue, the terms of the contract should govern. The property built by the corporation under the terms of its charter or franchise, whether the items belong to the corporation or the public, is the property to be reproduced. Franchise or contract provisions usually settle all questions of ownership or of division of joint expense. Such provisions should govern as to the inclusion of all, or part, of the expense in the reproduction estimate. It is immaterial whether another corporation or the public is the other joint owner. The division should be made on a proper interpretation of contract or franchise, and in such cases as those cited, no expense to be borne by the city under the contract should be appraised to the railway company, and no expense to be borne by the railway company under the contract should be omitted in determining the reproduction cost. The position taken in some cases, that such an expense as paving is not a permissible capital charge and therefore not an item of cost of reproduction in the case of a street railway, does not seem to be tenable when the expense is borne by the railway company.

When a corporation is required, as is usual, to remove and replace paving when constructing works requiring such removal and replacement, there can be no doubt that the existence of pavement in a street makes the construction of tracks, or the laying of pipes or conduits, more costly than if the pavement were not there. When pavement exists, therefore, at the date of estimate, its effect on the cost of reproduction cannot be ignored, even though the extra cost should not be included when using the reproduction cost as an element of "fair value". The item when included should be scheduled separately, so that it can be omitted if that be the will of the determining body.

This subject has already been referred to under the caption "Title to Property Not Conclusive", on pages 1748 to 1751.

The item of clearing and grubbing railroad rights of way is one concerning which question has been raised. On few if any rail-

roads, is there any forest on the right of way. Along many miles of existing railroad there is to-day no evidence that there ever was any forest growth on the right of way, where history shows the existence of dense forests at the time of original construction. It is true that this is a minor question, because the rise in land values, if allowed, will in general—but not always—more than offset any possible loss to the company-owner by reason of the exclusion of the item of clearing and grubbing actually paid for, but no longer in evidence as ever having been necessary. The fact, that there may be offsetting advantages and disadvantages, does not affect the principle involved. The effort is to get a basis for the present-day value of the owners' investment. If, as a result of human progress, it would be reasonable to suppose that, at the date of valuation, the land occupied by the railroad would have been cleared, regardless of the existence of the railroad, and it is so cleared, it would seem to be fair to omit clearing from a reproduction estimate. If, on the other hand, it is fair to assume that, but for the presence of the railroad, the forest would still be there, the cost of clearing and grubbing should be allowed. There are cases in which one, or the other, of the assumptions herein made is clearly the correct assumption, there are other cases in which it is not so clear, as to whether the changed conditions are due to the railroad itself. Let it, as the party bearing hazards, be given the benefit of the doubt.

Another class of expenditures, that may be greatly affected by the choice of historic or present-day conditions, is that including promotion, organization, financing, interest during construction, and some other overhead charges, development expense, and the excess cost of piecemeal construction.

There will be no difficulty with respect to newly created properties. The question occurs with respect to old properties of magnitude, that have grown from relatively small beginnings.

In such cases most of these expenses would be relatively large for the original enterprise, and relatively small, or nothing at all, for the smaller additions as they have been made from time to time—although interest would always be an expense, and the others named would be incurred in greater or less degree on all but minor additions. And it may very well happen that important additions may be of such relative magnitude that all of this class of expenditures will be as large, in percentages of the property to which they apply, as were the original expenses of this class of the original property.

It would seem, therefore, that with respect to these items, the policy should prevail, of referring to the history of the property, to determine to what portion of the property, and how these items of expense, are properly applicable, just as has been advised for the determination of those items of physical property that are to be in-

cluded, not forgetting that at least the item of interest is applicable to the whole of the construction, but for varying lengths of time, and that development expense attaches to practically all additions of any considerable relative magnitude, and the excess cost of piecemeal construction to all minor additions.

Concerning facilities for doing work in general it would seem to be logical to use those of the period of valuation, but with respect to transportation agencies, this may work injustice in some cases. The Los Angeles Aqueduct, and certain other works, all built without near-by railroads to bring materials, men, and supplies to the site of the work, could now have the advantage of more recently constructed railroads. Have these great works, fully serving their several purposes, lost a considerable portion of their value by the development of transportation facilities not in existence when they were built? It would seem fair to say "no", even though this may seem to be inconsistent with the position taken with respect to most old properties. The uncertainties with respect to the details of facilities existing, or used in the construction of old properties, and the effect of these on unit prices, which, as will appear later, the Committee thinks should be as of the period of valuation for reproduction estimates, make it seem desirable and consistent to use present-day transportation facilities for most old properties, and historic facilities for some exceptional cases of old or recently constructed properties.

The conclusion of the Committee is that, while apparent present-day conditions, that would affect the cost of reproducing the property, must be considered in any logical estimate, yet history must also be considered to determine what is to be reproduced, the conditions under which it is to be reproduced, and how the estimates must be made; that for all those items, concerning which there can be no doubt, the engineer should use the basis plainly applying, and that for those that are doubtful, or have been questioned, he should present the effect of the use of the different bases clearly, that the determining body may have the data for a wise decision.

2.—Shall Present or Original Prices Govern?—Prices for labor and materials rise and fall, and the cost of doing work varies, as new machinery and appliances are invented.

The term "present prices" has sometimes been held to mean the prices of the day of estimate; sometimes the average prices of a greater or less period just preceding the day of estimate; and sometimes the prices of a similar period just following the day of estimate. By the term "present prices" the Committee means prices averaged over a period of time to produce what may be called normal prices, as is fully discussed under the caption, "Unit Prices".

One of the recognized bases of "value" of property is the sum that it would cost to produce that property or an exactly identical

property at the present time. Estimates of the "cost of reproduction" are made to show what the property could be produced for new at the time of appraisal, and therefore unit prices which were actually paid many years ago may not now apply. It would seem to be clear that, in estimating the cost of producing any property at a given time, unit prices which do not and cannot prevail at the time of the investigation should not be used; and, conversely, it would seem to be equally clear, without argument, that the prices for materials and labor should be those of the assumed time or period of construction.

Important decisions of the United States Supreme Court, on which the Committee bases its conclusion, that present prices for materials and labor should be used, are Willcox *vs.* Consolidated Gas Company and the Minnesota rate case. In the former, Mr. Justice Peckham says (212 U. S., 19, January 4th, 1909):

"And we concur with the court below in holding that the value of the property is to be determined as of the time when the inquiry is made regarding the rates. If the property which legally enters into the consideration of the question of rates has increased in value since it was acquired, the company is entitled to the benefit of such increase. This is at any rate the general rule."

The decision referred to is that of Judge Hough in Consolidated Gas Co. *vs.* City of New York (157 Fed., 849, December 20th, 1907).

"Upon authority, I consider this method of valuation correct. What the court should ascertain is the 'fair value of the property being used' (Smyth *v.* Ames, 169 U. S., at page 546, 18 Sup. Ct., at page 434 (42 L. ed. 819)); the 'present' as compared with 'original' cost; what complainant 'employs for the public convenience' (169 U. S., at page 547, 18 Sup. Ct., at page 434 (42 L. ed. 819)); and it is also the 'value of the property at the time it is being used' (San Diego Land Co. *v.* National City, 174 U. S., at page 757, 10 Sup. Ct., at page 811 (43 L. ed, 115)). And see, also, Stanislaus Co. *v.* San Joaquin Co., 192 U. S., 201, 24 Sup. Ct., 241, 48 L. ed., 406. It is impossible to observe this continued use of the present tense in these decisions of the higher court without feeling that the actual or reproductive value at the time of inquiry is the first and most important figure to be ascertained, and these views are amplified by San Diego Land Co. *v.* Jasper (C. C.), 110 Fed., at page 714, and Cotting *v.* Kansas City Stock Yards (C. C.), 82 Fed., at page 854, where the subject is more fully discussed. Upon reason, it seems clear that in solving this equation the plus and minus quantities should be equally considered, the appreciation and depreciation treated alike. * * * The so-called 'money value' of real or personal property is but a conveniently short method of expressing present potential usefulness, and 'investment' becomes meaningless if construed to mean what the thing invested in cost generations ago. Property, whether real or personal, is only valuable when useful. Its usefulness commonly depends on the business purposes to which it is or may be applied. Such business is a living thing,

and may flourish or wither, appreciate or depreciate; but, whatever happens, its present usefulness, expressed in financial terms, must be its value."

"As applied to a private merchant or manufacturer, the foregoing would seem elementary; but some difference is alleged to exist where the manufacturer transacts his business only by governmental license—whether called a franchise or by another name. Such license, however, cannot change an economic law, unless a different rule be prescribed by the terms of the license, which is sometimes done. No such unusual condition exists here, and, in the absence thereof, it is not to be inferred that any American government intended, when granting a franchise, not only to regulate the business transacted thereunder, and reasonably to limit the profits thereof, but to prevent the valuation of purely private property in the ordinary economic manner, and the property now under consideration is as much the private property of this complainant as are the belongings of any private citizen. Nor can it be inferred that such government intended to deny the application of economic laws to valuation of increments earned or unearned, while insisting upon the usual results thereof in the case of equally unearned, and possibly unmerited, depreciation."

"I think the method of valuation applied by the report to land, plant, mains, services, and meters lawful."

In the Minnesota rate cases, Mr. Justice Hughes says (230 U. S., 352, June 9th, 1913):

"It is clear that in ascertaining the present value we are not limited to the consideration of the amount of the actual investment. If that has been reckless or improvident, losses may be sustained which the community does not underwrite. As the company may not be protected in its actual investment, if the value of its property be plainly less, so the making of a just return for the use of the property involves the recognition of its fair value if it be more than its cost. The property is held in private ownership and it is that property, and not the original cost of it, of which the owner may not be deprived without due process of law."

The Committee believes that the foregoing decisions require the use of present rather than original prices in estimating reproduction cost. It recognizes, however, that undesirable fluctuations in the estimated value of property valued at intervals would occur owing to changes in prices. It suggests that this may be avoided and the value from year to year of a property which has been once properly valued may be determined if proper methods of accounting are adopted.

In the case of a new or recently created property, which has had from the beginning, under continuous and proper regulation, a modern system of accounting, which has taken account of all proper capital charges and credits, so that the amount of invested capital would be known at all times, such invested capital would be entitled to greater weight on equitable grounds as an indication of the so-called "fair

value" than an estimate of cost of reproduction less depreciation which might involve radical changes of prices; but we are not now discussing original cost to date, nor what is the proper basis for "fair value". For reproduction cost the Committee recommends that, in estimating, the prices prevailing at the assumed time of reproduction shall be used, meaning the normal prices obtained by averaging prices for a proper period, as is fully discussed subsequently in this chapter under the caption, "Unit Prices".

3.—Shall Identical or Substitute Plant be Considered?—Occasionally an estimate has been made, not of what it would cost to reproduce the existing unit, but of what it would cost to produce some substitute unit which would perform the same function as the existing unit.

For example, in a valuation of an old railroad, it was found that all the bridge piers and abutments and retaining walls built in the early years of the property were of stone masonry which would cost to reproduce new from $12 to $16 per cu. yd., and that all work built during the last 10 years was of concrete costing from $7 to $11 per cu. yd. It was argued that the modern construction, built at less expense, fulfilled exactly the same functions, and that, if the property were actually to be reproduced, stone would not be thought of. Undoubtedly, the original construction was used because it was the best available, and, in the judgment of the engineer and directors, this was a proper expenditure.

In one other case an engineer was making an appraisal of a large electric plant furnishing lights to a large city and power to several hundred miles of railroad. The power plant as originally built had been outgrown, and a second plant had been built alongside with about equal capacity. Both plants were working to capacity during the peak load, and both plants were well maintained. It was argued that one modern, up-to-date plant could be built which would cost less than the reproduction cost of the two and perform the same function.

Other illustrations of properties, which have been expanded to meet the need of rapidly growing cities and which in their present form represent very much larger investments of capital than would be necessary were actual new construction to take place at the present time, are afforded by the water supplies of some American cities. One western State capital affords an excellent example. The first water supply was obtained by pumping from a near-by source. Later, a supply was secured some 20 miles distant, but, in order to make use of an infiltration gallery, the water was taken at a point elevated only slightly above the distributing reservoir in the city, so that the capacity of the pipe was small in proportion to its size, on account of the limited fall. Large filter beds were located at this place; still later, an intake was located farther up stream, which made available a greater fall to the reservoir in the city; another feature is a large

natural lake used as a reservoir, fed by a small stream, not very far from the pipe line between the main source and the city, but at a higher level; still later, a great reservoir with a dam more than 200 ft. high was built in the mountains, far above the main source of supply.

It probably cannot be said that the company did not use reasonable judgment in the laying of each of the pipes and the building of the reservoirs and filters referred to, but if one were to design an equally efficient plant at the present day the water could be taken from farther up stream, so as to have an adequate head; it could be brought quite near to the city in a masonry conduit which would cost much less for the same quantity of water than the existing pipes; the lake or reservoir could be utilized at this level as a storage reservoir connected with the main supply; a single filter plant at the proper elevation, much higher than the present one, could be located comparatively near the city as a substitute for several independent filter plants; and two pipes having the same aggregate capacity as all the existing pipes leading from this filter plant to the city would cost much less than the existing pipes because of the much greater available fall. To use the estimated cost of the substitute plant in this city in lieu of the estimated reproduction cost of the present property would ignore a large investment actually and properly made by the water company.

The cost of reproduction being always required for the establishment of some relation between the public and its servant, the service corporation, either with respect to rates for service, purchase price, capitalization, or taxation, it would seem that the company should be credited with what it has actually produced in good faith and with what seemed to be good judgment at the time the property was created.

In the cases cited, the cost of substitute plants or property units altogether different from those actually built would vary very much from the reproduction cost of the existing property, and although such a substitute property, much less costly than the existing plant, might furnish equal or better service, it is not reproduction of service, but of property, that is under consideration; and clearly the estimate should be of existing property created with public approval, rather than of a substituted property.

In the case of the valuation of obsolete units of property still in service, where the unit is of a type not on the market and not possible to reproduce in kind at the present time at reasonable cost, it may be desirable to use the cost of a modern unit capable of performing the same service, but this would appear to be the only exception, and would seem to apply only to individual units, such as machines, which are not capable of being estimated by ordinary standards used in reproduction.

Reproduction in kind deals with facts, with properties that have physical existence and can be measured, inspected, and in many cases

their actual cost determined. Production of a substitute would be based more largely on speculation; different engineers would undoubtedly differ in their views as to the location, design, and cost of the substitute plant, and an estimate based on such a plant would be more difficult to support than one based on an existing plant, by reason of conflicting expert opinion as to the proper procedure.

Although the cost and efficiency of the substitute plant may have some bearing on the value of the existing plant, remote though it may be, it has none on reproduction cost of the existing property.

These views are in accord with the general practice of engineers who have engaged in appraisal work. These engineers have valued the identical property, and this method of valuation, when brought before the various Courts, including the Supreme Court of the United States, has met with approval, although the relative merits of the two methods have not been discussed by the Supreme Court. The principle that the identical property should be valued has been accepted apparently without discussion.

In the case of the Consolidated Gas Co. *vs.* City of New York, Judge Hough says:

"In every instance, however, the value assigned in the report is what it would cost presently to reproduce each item of property in its present condition and capable of giving service neither better nor worse that it now does. * * * Upon authority, I consider this method of valuation correct."

In the case of the Kennebec Water District *vs.* City of Waterville, Judge Savage says (at page 19):

"We think the inquiry along the line of reproduction should, however, be limited to the replacing of the present system by one substantially like it. To enter upon a comparison of the merits of different systems—to compare this one with more modern systems—would be to open a wide door to speculative inquiry, and lead to discussions not germane to the subject. It is this system that is to be appraised, in its present condition and with its present efficiency."

In harmony with the foregoing arguments, it is recommended that, for whatever purpose in connection with the relations of the public and the service corporation the cost of reproduction is required or desired, the estimate should be made with respect to the identical property, and not with respect to some substitute property to perform the same service.

4.—What is Meant by the Word "New", in the Phrase "Cost of Reproduction New"?—The words "Cost of Reproduction New" are of such frequent occurrence in valuation cases, and seem to have given rise to such diverse views, that, before the proper conception can be finally determined, it is necessary to give consideration to the proper weight to attach to the word "New".

For example, a certain logging railroad is 51 miles long. It was laid entirely with relayer rails; ten second-hand locomotives and certain second-hand cars were purchased and have been used for some years. It would be permissible under some conceptions of reproduction to estimate all this rail and equipment as new, but, such a conception would not appear to be proper. The term "new" in a case of this kind would apply to the character and condition of the second-hand materials as they were originally installed, and their depreciation would be measured by the difference between their condition at that time and at the date of valuation. The rail and the equipment are larger and more expensive than the road would be justified in buying if it bought them new. The property as "reproduced", if conceived to be new rail and equipment, is not identical with the original property when it was "new" or first built. There are costs estimated which did not enter into the original investment.

Another example.—On a little draw-bridge a motor has been installed which is in fact an old street railway motor capable of performing its new function indefinitely. It is of much greater capacity than would be needed for the bridge, and if a new motor had been installed a much smaller and less expensive type would have been selected.

In the examples cited it would seem that the properties when created "new" were partly second-hand, and the reproduction estimate should include relayer rails at relayer prices, second-hand equipment and second-hand motor at prices fair for the actual items at second-hand.

The Federal Valuation Act particularly requires that there shall be found: "The original cost to date; the cost of reproduction new; the cost of reproduction less depreciation."

In view of the wording of the Valuation Act, some have assumed that the word "new" requires the assumption of new rail in making a valuation, but that where records show that the material in the road was originally second-hand material, and is at present second-hand material, an initial depreciation equivalent in amount to the difference between the cost per ton of new rail and the cost per ton of relayer rail, such as was used, may be entered under the depreciation column. A further examination of the property itself at date of valuation will determine whether or not there is any additional depreciation, and to what extent it exists.

We speak of a new property and thereby refer to a property which has been created where no such property existed before. It may be of new material in all its parts, or it may be "new" as to grading, ownership of land, and many other of its elements, but have second-hand material and equipment entering largely into its construction.

If substitute units are to be excluded from consideration, consist-

ency demands that original conditions of existing units in their present service must be restored, and that no interpretation of the word "new" is to be permitted which places a property unit in any better or worse condition that it was in when first installed in present service. The property to be reproduced is the existing property. Each unit of property which is in existence is to be reproduced in the same condition as it was when it was put to its present service.

Conclusion as to the Proper Conception of Reproduction.—In line with the foregoing discussion, the Committee recommends that reproduction estimates be based on the assumption that the identical property is to be reproduced, rather than a substitute property; that while apparent present-day conditions, that would affect the cost of reproducing the property, must be considered in any logical estimate, yet history must also be considered, to determine what is to be reproduced, the conditions under which it is to be reproduced, and how the estimates must be made; that for all those items, concerning which there can be no doubt, the engineer should use the basis plainly applying, and that for those that are doubtful, or have been questioned, he should present the effect of the use of the different bases clearly, that the determining body may have the data for a wise decision; and that normal present conditions shall determine the prices and methods for doing the work.

Work Preliminary to the Making of the Estimate of Reproduction.

The Schedule.—The first step in estimating the reproduction cost of a property is such a study of the property and its history as will enable the estimator to make a complete list of all items, lay out a proper financial and construction programme, and fix proper unit prices to the several items of the schedule.

Every appraisal offers its own problems, and it would be impossible for the Committee to lay down any fixed rules for the detail of appraisal that would be of universal or even of general application.

When the records of a company owner—maps, plans, specifications, deeds, and other titles to property—engineering records of construction and accounting records are sufficiently complete, it may be possible and permissible to make up schedules from the records and depend on inspection in the field to furnish a check on the records and to apply information to make good any deficiencies. Where, however, as is often the case, the records are incomplete and fragmentary, it becomes necessary to make most careful field schedules of the property, using the records as far as practicable to check field measurements and to furnish as much light as possible on the history of the construction.

Classification of Property.—For scheduling, the property should be divided into groups of items or units, preferably following some well-

established classification of accounts. For example, in railroad valuation, the grouping of items in each schedule should follow the grouping in the corresponding account of the Interstate Commerce Commission's Classification of Property chargeable to capital accounts. Where units of property or items of cost appear to have no place in such classification of accounts, but are clearly part of the cost of the property or are claimed as such, they should be set up as a sub-group, in the account that appears to be most appropriate.

Field Schedules.—When it becomes necessary to make surveys or field inspections in order to prepare the schedules, it is desirable that each property unit in each schedule be described so fully, and identified by such complete measurements, that no question could be raised as to its identification or as to the propriety of the use of the unit price that is subsequently assigned to it. It is entirely possible to prepare, based on field work alone, complete schedules of all visible physical property of a company operating any sort of a public utility, but it must be borne in mind that such schedules are not complete, because they ignore the history of the construction, and that by no means all the legitimate cost of creating or reproducing any property is represented by visible physical property, even where every item is capable of being fully measured. Careful consideration must be given to such history as shows any specially favorable or unfavorable conditions that may have been encountered during the construction of these items.

It must be emphasized that all items of material or work which entered into or were incidental to actual existing units are to be considered in the reproduced units as far as they can be determined.

Use of Records.—Most careful study of all existing records constitutes an essential part of the work of a reproduction estimate. Every plan, note, or cost record existing which relates to a plant unit measured and described in the field should be studied so that error may be eliminated and full data secured. It frequently occurs that plans are made for a structure and that during construction changes were made without notation on the original plans, such changes being indicated by fragmentary supplementary plans which are not preserved, or by no plans at all. In all such cases the appraisal record should correct the existing record as completely as practicable. Existing records should be used to the fullest extent to identify invisible items of property, such as underground construction or other inaccessible property, and to establish the nature and condition of existing items when originally installed.

Additional Information Not in Official Records.—Occasionally a case will be encountered where the history of the property is not to be determined with any degree of completeness from existing records, but on inquiry among former officials, former employees, consulting engi-

neers, contractors, or others who may have had connection with the property during all or a part of the building period, a large amount of thoroughly reliable information may be had which will throw great light on history and on costs. The use of all such data is highly desirable.

Little dependence should be placed on mere gossip or recollection unaided in any way by record, especially if it involves any increase in cost beyond a normal figure.

An illustration of the advantages to be gained from such an inquiry occurred in a recent valuation on a mid-western interurban railway. One of the branches of this road had been built as an independent line which changed owners once before coming into the hands of the present company. Aside from maps, a top-of-rail profile, and general data as to structures, all of which had been secured by a recent survey, the company had no records, not a word as to history, and nothing as to original cost. Inquiry developed the fact that all the construction records had been stored in the office of one of the officials, had not been turned over to the second owner, and after the death of this former official had been sold for old paper. Further inquiry yielded the names of one or two contractors. One of these men was visited. He went through his vault and unearthed complete profiles, copies of all progress and final estimates for grading, bridging, and track laying, plans for several bridges, and a large volume of construction photographs. With his aid, the men who purchased the right of way were found, and by their correspondence and receipts the original cost of most of the right of way (none of which was disclosed by deeds) was secured. This search disclosed the fact that many expenses were incurred which would not be even surmised by an examination of the property.

It is clearly the duty of the men engaged on an appraisal to take every precaution to secure to the fullest extent all data bearing on the actual work of construction as, in making an estimate of the cost of reproduction, due weight must be given to all evidence showing what the actual construction of the property included.

No Specific Assumptions as to Difficulties Where Not Capable of Proof.—In cases where no records are obtainable which will supplement actual field measurements and observed conditions, it would appear that the only proper course is to base the estimate of cost of reproduction on each unit of property as measured, assuming it to have been built under conditions which may be presumed from recent surroundings. To assume that the unit in question would cost less or more than the average unit, or that work has been omitted, or extra work done, in the case of a specific unit, when there are no records or obtainable data and nothing in the general property to justify the assumption, would be conjectural and carry little weight.

The Field Inspection.—The Committee deems it to be no part of its duty to undertake to outline methods in detail. It is proper to emphasize the necessity of full and complete records of field inspection in such form that they may be readily used in computation and fully indexed for filing. There is always a possibility of doubt regarding plans and records of old properties, uncertainty as to changes or abandonment, and, unless supported by field work, many really valuable records may be minimized in importance. It must be borne in mind that valuation work, especially the making of schedules, is of permanent value as a record of property, and that its value as a record for the Courts depends on the completeness of the description and identification of each property unit.

Many uncertainties can be cleared up, and much of the speculative character of estimating past conditions can be eliminated by good field work. There is a lack of significance, a failure to meet the requirements of appraiser or Court in every case where field inspection is hastily or carelessly made or no adequate record is made of the work.

Forms for Field and Office Record.—The use of forms is becoming so general and their value in securing uniform information from different field men is so great that there seems to be no ground for questioning their desirability or the propriety of their use. There are so many different forms required on a large appraisal and so many have been devised in connection with appraisal work in progress in the United States that no attempt is made to discuss the subject or to make suggestions. The adoption of full, complete, and carefully drawn field and office forms for field notes, schedules, and inventories is approved practice. The more completely all pertinent data regarding any class of property can be developed on a single set of forms without transcribing, the more satisfactory and convincing is the record.

Unit Prices on Physical Property Other Than Land.

There is no more important consideration in connection with valuation work than the correct determination of unit prices.

Necessarily, every large valuation involves a special study of the conditions which affect cost of work in the community and on the property, and of actual costs of various classes of work on the property under investigation. The prevailing rate of wages for different classes of labor, local prices on material, freight rates on material, or local contract prices, are by no means the only matters which are to be considered and taken into account.

Unit prices, or unit costs, which are finally determined upon and adopted as multipliers in the schedule should contain every element of cost which can be determined and allocated to each particular item.

A very erroneous result is likely to be secured if the appraiser adopts net cost for materials delivered to the property as shown by the vouchers for material, and actual contract figures for labor items, because in general these do not take into account all elements of cost to the owner.

In arriving at unit prices for final application, all relevant facts must be considered, and eventually sound judgment must be brought to bear on all data, if a proper unit is to be secured. The Committee desires to emphasize the fact that in the adoption of unit prices there is wide room for variation and error. A schedule may be made with the greatest of accuracy, field inspection may be most elaborate, and every possible check may be applied to the computations, but, if unit prices are carelessly adopted, which are too low or too high, a considerable error may be made easily in the valuation of tangible property.

The unit prices on most of the items entering into a valuation are not capable of exact and absolute determination or proof. This is especially true of all items in which labor largely enters into the cost.

The correctness of the figure finally adopted in every case depends in large measure on the reliability of records of actual costs, of similar units in recent years, the thoroughness of the study that has been made of those records, and the experience and soundness of judgment of the appraiser in the use of these studies and of other supporting data.

In the determination of unit prices the following general matters must be considered:

1.—What allowances should be made for contractor's profit in fixing prices?

2.—Shall unit prices be averaged over a period of time or shall actual prices as of the date of valuation be used?

3.—To what extent shall prices prevalent in piecemeal construction be considered?

4.—What should be included as elements of unit cost in fixing the price to be used?

1.—Contractor's Profit.—In assuming the reproduction of a property, the most reasonable assumption in general is that it would be let by contract, and that prices should be applied which would include the profit of contractors engaged on the work.

The fair total contract cost of the work, after award on fair competitive bidding, constitutes an equitable basis of unit cost determination, such cost including a reasonable profit to the contractor and necessary sub-contractors. To this should be added incidental unit

costs, overhead, administrative, and general costs incurred by the corporation, which are definitely assignable to the different units of property as part of the unit price.

There are cases, however, in which it would be a proper assumption that the company would establish its own organization, purchase its own plant and material, and do its own work.

The extent and character of the property under investigation, the actual history of the construction of the property itself, or the general practice in the part of the country in which it is located, will be the determining factors in arriving at the proper assumption to adopt.

When it is proper to assume that the company does the work itself, the estimated full cost to it should govern, including in the estimate proper recognition of the use of plant, hazards, and the fact that changes, modifications, and adaptation of the original plans generally occur and involve increased cost over the estimate, but no contractor's profit; unit prices should then be used, which represent what the estimated total unit cost to the company would be, by the method assumed to be proper.

2.—Shall Average Prices or Prices as of a Certain Date be Used? —When a valuation is made as of a certain date, it must be determined whether prices of materials and labor as of the date in question shall be used, or whether prices averaged over a period of years are more proper.

A study of the trend of prices of various commodities shows widely differing conditions. For example, Bessemer steel rail has remained steadily at $28 per ton, f. o. b. mills, since 1901 until recently; in some sections of the country lumber has increased with a fair degree of uniformity from 1901 to the present time, oak showing more than 50% increase, white pine more than 100% increase, and hemlock more than 50% increase; Portland cement, on the other hand, has decreased in some localities from $3 in 1880 to about $1 per bbl. in 1915, but increased in the year following; labor has steadily increased in recent years, with the upward trend still noticeable.

Other materials—an example of which is copper—have fluctuated, going up and down from extreme high to extreme low figures without any relation to changes in labor or other material prices. These facts compel most careful analyses of the records of the property under appraisal, and of other like properties in the same vicinity, to determine price tendencies, actual costs of work done, and special local conditions which affect costs, if average prices are to be used.

The illustration afforded by the Buffalo gas case (3 P. S. C., 2d Dist. N. Y., 1913), is given as showing the effect on valuation of price fluctuation. There were almost exactly 30 000 tons of cast-iron gas

pipe in question. The Commission summarizes the fluctuations as follows:

In 1897 when the property was taken over this would have been worth, at the prevailing price.	$547 500
Had a valuation been made in 1907, it would have been worth, at the price of that year.......	1 200 000
On the average prices of 5 years, 1893 to 1897....	617 700
On the average prices of 5 years, 1898 to 1902....	746 700
On the average prices of 5 years, 1903 to 1907....	944 400
On the average prices of 5 years, 1908 to 1912....	720 600

It seems to the Committee that what is desired is what may be termed normal present-day prices.

By normal, present-day prices is meant such prices, actual or average, as will be fairly representative of the period, but which do not reflect violent fluctuations up or down. These normal prices will be to some extent affected by changes in the market.

Many commodities, of which cement is an example, have had a downward trend, owing to increase in home manufacture and to improvements in the art. Other commodities, like lumber and timber of all kinds, have steadily increased in price owing to decreasing supply and greater demand. There can be no serious question as to the propriety of the use of normal, present prices, or prices averaged over 2 or 3 years at most, rather than the use of a long average which would bring the price above or below a proper, normal, present price.

In the case of such materials as iron pipe and copper, the price fluctuations of which have been violent during short periods, the problem becomes specially difficult. The actual construction of all large properties has extended over a period of years. An investigation of actual costs of construction on large properties will generally disclose the fact that materials have actually been bought at both high and low figures; frequently large quantities will be bought near one limit or the other. Actual cost, where ascertainable, gives actual investment in this material. Actual cost is not always capable of determination over the entire life of a property, and for such material as entered in during such period some arbitrary unit must be adopted, even in the case of "original cost" estimates.

The practice, adopted on some recent appraisals, of using a price derived from a weighted average of actual purchases over a period of from 5 to 10 years on the property under investigation, has the merit of using actual investment in recent years as a basis for determining a unit to be used on the entire property, and meets the objection raised by the Second District Commission of New York.

Present-day labor prices can be determined by an analysis of payrolls over such a length of time as will give proper actual averages

for each class of labor. By a comparison with similar data derived from records of other properties in the immediate vicinity, prices may be derived which are actual and are capable of proof. Prices thus determined would seem to be proper bases on which to build up estimates of total labor entering into the various units.

Any price which is used must be a matter of judgment, in the light of all available facts, but the arbitrary selection of a certain specific date as the date of appraisal does not seem to justify the use of prices which are abnormal. However derived, the prices used for fluctuating materials should be proper for the estimated period of reproduction which should end with the date as of which the investigation is made, and which should be sufficiently stable so that no reappraisal within a short time thereafter should make violent changes in estimates of reproduction cost.

3.—Piecemeal Construction.—Piecemeal construction has been defined to mean that kind of construction which is done piece by piece, and not at a single operation.

For example, the original pipe system of water-works and some important additions may be laid continuously in one construction period, either by forces of the company or by contract, but many additions must be made from time to time to meet the needs of an increasing population and a growing demand for water. These are necessarily short stretches of pipe, widely scattered, and are almost universally laid by the forces of the company at considerably higher costs than would prevail if the work could be done in connection with the building of an entire distribution system.

There are many kinds of construction, which always are built in what may be termed a piecemeal manner, which are not built at the time of original construction. Such work as the installing of water, electric, or telephone services, the building of industrial tracks and spur-tracks on the line of a railroad, the setting of meters and other forms of construction, is generally done in response to the demands of business development. Every effort of the management is bent to securing the greatest economy in doing this class of work; records are kept, and actual costs can be obtained over almost any period desired. Unit costs for this class of work can be determined from actual costs which are capable of very exact analysis and very definite proof by comparison with similar actual costs on other properties.

Whether or not unit costs should be determined on the basis of piecemeal construction, or on the basis of doing the work in a wholesale manner, depends upon the assumptions which are made with regard to the method of development of the property under which the estimate of reproduction cost is to be made. If on the basis of historic sequence, then the extra unit cost of piecemeal construction should be included; if on the basis of reproduction under present con-

ditions, during one construction period, then the extra unit cost of piecemeal construction should in general be excluded—the exceptions occur when it is assumed that the business is to be gradually developed in an assumed further period, in which cases it would be proper to use piecemeal unit prices for those items which would be so produced.

In the reproduction estimate, the property should be assumed as reproduced in the most economical manner and in reasonable sequence. Such assumption of necessity involves the building of some items of property that develop with the growth of business, not as part of the main property, but as following the main property, and at unit prices which would represent the actual cost of similar items of property built as they necessarily were or would be likely to be built by methods different from, and in some cases more expensive than, those that could be used on the main property.

4.—What Should be Included as Elements of Cost in the Unit Prices?—There has been an unfortunate lack of uniformity in valuation practice in the manner of arriving at the estimate of reproduction cost.

Apparently, some engineers have used material prices which were based on net costs at the point of delivery, and labor costs based on contract prices for performing certain work, and then, realizing that these do not give complete cost, but without making a full analysis, have added percentages to the total valuation for omissions, contingencies, incidentals, errors, contractors' profit, or other blanket items.

It may be that such a method, when used with good judgment, will lead to a result which is as close to the truth as when a more elaborate analysis is made, but it is much more difficult of satisfactory proof.

In the opinion of the Committee, the unit prices which are applied to specific items of property should include every element of cost to the owner capable of definite assignment to those items, and no such elements should be included as a blanket, overhead charge.

For example, the material may be purchased in the open market, the normal price may be capable of determination, and the freight rate to the point of use may be secured and applied, but to these two main elements there should be added, wherever they are properly applicable and obtainable:

(*a*)—The cost of purchasing;
(*b*)—House or material yard service;
(*c*)—Local transportation;
(*d*)—Waste, loss, and breakage;
(*e*)—Direct supervision.

(*a*)—*The Cost of Purchasing.*—The organization and expense of the purchasing department might with propriety be treated as an over-

head charge; it may with equal propriety be treated as a charge to material, and is capable of determination with definiteness in most cases. In the case of a large operating company, where purchases cover material for maintenance and also large expenditures for construction, there is grave danger of overlooking this item of expense. Usually an analysis of the accounts will give actual costs of purchasing of large quantities of material, thus permitting an allocation of purchasing costs on construction material.

(*b*)—*House Service or Material Yard Service.*—The cost of warehousing, material yard handling, or what may be termed "House Service" or "Material Yard Service", is an expense which on a large property is great in the aggregate although a comparatively small percentage on cost of material purchased. The extent of the charge and its division depends on how much of the material is purchased for direct delivery, how much goes through a material or storage yard, and how much goes into a warehouse for delivery in small lots as needed.

(*c*)—*Transportation.*—In almost all valuations, the greater part of the material involved incurs a transportation expense over and beyond the railroad freight rate to the point of delivery. In the case of railroad materials of all kinds, the material is usually purchased, f. o. b. cars, at the most convenient delivery point on the line of the road, and a haul of possibly several hundred miles on the company's own line is necessary. The determination of the average length of haul for the material of each class on a railroad and the determination of a proper rate to apply constitute a very important element in the determination of the correct unit prices. In connection with this matter of the rate, attention may be called to the fact that, under construction conditions, on a new road, with traffic all in one direction, without the advantage of an old established operating organization, the cost will exceed the cost of service on an old road. This has been recognized by the Oklahoma and California Commissions.

The local transportation may consist of haul by truck or wagon to the site, and, if so, is a present element to be computed, if not otherwise provided for. In estimating cost of transportation, it is to be assumed that all transportation facilities existing at the date of estimate—except the property under consideration in case it is a transportation property—are available.

(*d*)—*Waste, Loss and Breakage, or Overplus Over Measurements.*—These are elements of either unit cost or of allowance in measurement of quantities rather than of contingencies, for the reason that they vary so greatly, from nothing at all on some materials to a very considerable percentage on others. In this class would come allowances for sag in wire or cable, waste in lumber, loss and breakage in fragile materials, and all other allowances over net quantities which are necessary to in-

sure enough material to complete the work. In the case of some materials, quantities are derived by rules which give theoretical or geometric quantities, though the actual quantities moved and paid for may considerably overrun.

One very notable example of this is given in the Panama Canal Report for the year ended June 30th, 1912, which states that the geometrical quantity in the dredged channel of the Panama Canal, from deep water on the Atlantic side to a short distance beyond the shore line, was to that date 10 169 000 cu. yd., though the actual quantity taken out of the channel amounted to 22 886 000 cu. yd., an excess of 125 per cent. The great excess of dredging in this case over the geometrical quantity was due to the quantity of material washed into the channel by waves and currents.

There are certain standard weights of cast-iron water pipes, and pipes of these weights are ordered. As the pipe foundries cannot make pipes of the exact weight, the full price per ton is paid for any additional weight that there may be, up to a certain limit. The pipes are not allowed to run much below the standard, because it is provided that the thickness of the metal shall not be less than the prescribed thickness at any place by more than a very limited amount. The average actual weights, therefore, are more than the standard weights.

In valuing an earthen dam, the net volume in the embankment is generally measured or computed from the records, and it might be correct to use this net volume if the unit prices to be used were derived from the cost per cubic yard of other similar embankments. If, however, the unit prices to be used were derived from measurements of the quantity of material taken from borrow-pits for the purpose of building the dam, a considerable allowance should be made for the shrinkage of the material when placed in the embankment and consolidated, and for the waste of material which almost inevitably takes place in building a dam across a stream as the result of floods and other causes. The waste, as a rule, is exceptionally large when a dam is built by the hydraulic fill process.

It seems much better that judgment should be used in determining the actual quantities of material involved in a given construction than to make an allowance for such additional material as a contingency.

(*e*)—*Direct Supervision.*—*Inspection.*—It has been the custom in many appraisals to treat as an overhead charge, under the account "Engineering" all charges for Engineering, Inspection, and Supervision of work, and to base such charges on a general percentage of the entire physical property estimate.

The Committee holds the opinion that, wherever it is possible to do so, charges for direct supervision should attach to the different units or groups, rather than to the property as a whole, and that all

such charges as can be localized to certain materials, units, or groups should be treated as affecting the unit price, and should not be added as a percentage. This would permit the charge for general engineering to be treated as an "Overhead Charge" and include only those costs of general engineering, surveying, design, and supervision which were applicable to the property as a whole, and not capable of definite assignment to different groups of units or individual units of property.

As examples of elements of cost properly assignable to units or groups of units, the Committee cites the following cases:

The inspection cost on rail, water pipe, structural steel, and other materials purchased is capable of separation and inclusion in the unit price.

The local engineering and inspection costs of a large building, a dam, an underground conduit line, or other individual units or groups of units may be capable of analysis and comparison with like costs incurred in the construction of other like units, and a more accurate estimate is likely to be secured than if the total engineering charges be found as a percentage of the cost of the entire property, based on the experience with similar properties.

Each valuation must of necessity be an independent work, and each unit price should have such consideration as will insure that it is applicable to the case in hand, and that all elements, of which those above stated are only a part, have been taken into account. When unit prices for different items in the schedule are made up on the basis of the amount of labor involved, it must be remembered that the labor costs are by no means covered by the sums included for laborers on the pay-roll. There must be, in addition, proper allowances for insurance, injuries, and damages, lost time of monthly men, costs or losses due to interruption, or failure to co-ordinate the work at all times, decreases in efficiency due to such conditions, the cost of supervision, including accounting and timekeeping, and other actual costs.

When unit prices are based on contractor's prices, most of the items above mentioned would naturally be included by the contractor in such prices or as extra work, for which payment must be made to the contractor; but, wherever contract work is done, there is generally a considerable additional cost to the company as the result of subsequent work by its own forces.

Illustrations of Actual Cost Affecting the Cost per Unit.—One illustration which shows the extent of these items that have been referred to, and the desirability of more detailed analysis of costs than is frequently made, is that of an electric light and power property in the Middle West, in a city of more than 400 000 population.

During a period of $2\frac{1}{2}$ years, the company spent in construction $9 476 000, divided as follows:

Actual material entering into permanent construction.		$6 808 000
Actual labor costs in building permanent work.......		1 515 000
Total cost of labor and material in structures capable of scheduling.....................		$8 323 000
A.—Construction tools..................	$110 000	
B.—Store and supply expense..........	288 000	
C.—Purchasing expense.................	39 000	
D.—Injuries and damages..............	48 000	
E.—Engineering, general...............	122 000	
F.—Engineering, direct supervision.....	546 000	1 153 000
		$9 476 000

This does not take into account costs for interest, taxes, organization, or other costs which were incurred in the nature of actual overhead costs.

The aggregate cost, over and above those of bare labor and material, was 12.1% of the total, or 13.8% of the items capable of inventory.

It was found that full analysis of these costs gave very different percentages for different classes of construction, as for example:

Tool expense was approximately 2% of labor and material on overhead and underground construction, and 1% on buildings and equipment.

Stores and supplies expense, or the cost of handling, warehousing, and material yard, varied even more widely, as follows, being based on total material in each account:

Buildings	2.78%
Steam plant equipment...............	0.74%
Electric plant equipment..............	5.96%
Lines overhead and underground.....	7.35%
Other property......................	2.45%

Direct supervision, or those engineering and inspection charges which were capable of exact assignment, bore the following relation to total labor and material charges to each account:

Buildings	8.46%
Steam and electric plant equipment....	7.36%
Lines overhead and underground.......	4.60%
Other property......................	1.37%

These varying percentages are a strong argument in favor of more careful cost keeping on construction work and of more careful analysis

of existing records of actual cost, when a valuation of property is made.

Illustrations of Earthwork Unit Costs.—There are various classes of construction, such as earthwork, masonry, concrete, and other like construction, in which labor largely enters, where the conditions of construction may vary widely, and where there are available many contract prices, published or unpublished. The danger of basing a series of unit prices on contract prices, without analysis of further actual costs, may be shown by the discussion of one of these, and earthwork appears to offer a number of excellent examples.

In building a railroad or other property involving large quantities of earthwork, it is usual to pay for material, according to classification, as earth, loose rock, solid rock, etc. It is also usual to pay for overhaul beyond a certain specified haul limit.

In making estimates of cost of reproduction, unless all original notes, profiles, and estimates are available, it is a difficult and expensive matter to secure even a close approximation of actual yardage, and practically impossible to determine classification of loose rock, hardpan, or other material the character of which changes due to the effect of weather, or the identity of which may be concealed by growth of vegetation or otherwise. It is equally difficult to determine the quantity of overhaul or the amount of work which may have been done as a necessary incident to the grading of the embankment, such as changing of stream channels or roads.

All these things were encountered in the building of the property, and must in some way be accounted for in its reproduction. In some cases the unit price on unclassified earth in place is the fairest figure, and capable of better support than would be the attempt to classify or to separate overhaul.

In addition to these elements of cost which may be encountered in all earthwork, the railroad company encounters the expense to the company of transportation of men and contractor's plant, and the cost of work done after the contractor leaves the job.

The adopted unit price should be such a figure as will cover all expense, of every nature whatsoever, as is directly chargeable to grading the measurable embankment. Three or four examples will illustrate the possibility of grave error in failure to analyze unit costs sufficiently:

Example 1.—A high-class interurban railroad built in Michigan during 1912-13-14.—

Total material moved...............924 630 cu. yd.
Contract price of overhaul......0.01 per yd. station.
Hardpan, if encountered, to be paid by agreement.

In this case the company actually paid on its final estimate for:

774 387	cu. yd. earth	at $0.28	$216 828.36
1 860	" " loose rock	" 0.40	744.00
300	" " solid rock	" 1.00	300.00
776 547	Total classified material at prices named in the contract...............		$217 872.36
	In addition to which, there was allowed:		
148 083	cu. yd. "Hardpan" and "Wet Earth" at 38, 40, and 50 cents.....................		60 912.94
924 630	Total cu. yd., unclassified, at $0.30, average.		$278 785.30

It thus appears that the "rock" is a negligible item, but that the average cost of the unclassified material exceeded the contract price of earth by 2 cents per cubic yard.

In addition, the company paid:

For overhaul...	$29 237.51
For force account on work after contractors left...	13 988.42
Total.................................	$43 255.93

Thus making the total direct cost of the work $322 011.23, or an average of $0.348 per cu. yd.

Practically all of this excess was for elements of cost which could not be determined from either a careful reinspection of the property or from most accurate measurement, and, if reflected in the reproduction estimate at all, must appear in the unit price.

Example 2.—Among the exhibits introduced in the Minnesota rate case was one by A. R. Hogeland, M. Am. Soc. C. E., Chief Engineer, Great Northern Railway, entitled "Hogeland, 2d Amended Exhibit 4", which gives in detail the cost of grading on lines built between 1898 and 1910 aggregating 1 553.2 miles. This exhibit shows the contract prices for each class of material, and also the total charges to grading. The exhibit shows the details for each line built during those years.

A very brief abstract of this exhibit shows:

Earth...	28 693 523	cu. yd. average contract price	19.3 cents	$5 545 074.31
Hardpan	9 260 156	" " " " "	34.7 "	2 211 293.53
Loose rock..	3 115 093	" " " " "	40.7 "	1 270 666.25
Solid rock..	6 209 349	" " " " "	94.7 "	5 876 720.69
	47 278 121	" " average of all......	33.6 cents	$15 903 754.78

Brought forward..................	$25 832 480.43
It is to be noted that, over and above these contract prices, the company paid for overhaul, force account items, transportation, and other such charges, the total sum of..	4 928 725.25
Total cost..................................	$25 832 480.43

Average cost per cubic yard..........	44.11	cents
Cost in excess of contract price.......	10.5	cents

These figures are affected by the large yardage of rock, which presumably could be largely determined in a valuation. In order that rock be eliminated, an analysis of this exhibit was made and 300.29 miles having no rock were tabulated separately.

On this mileage the total yardage moved was 3 293 244 cu. yd.
Total contract price, $506 869, an average of 15.4 cents per cu. yd.
Total Company cost over contract, $264 727, or 8 cents per cu. yd.
A total cost of $771 596, or 23 cents per cu. yd.

It is here shown that actual cost per unit exceeded contract price per unit by 52.22 per cent.

Example 3.—A steam railroad built in Wisconsin in 1912 and 1913:

Total contract price for grading......................		$1 259 567.81
Extras		
Contractors extra bills................	$42 830.86	
Railway Company labor..............	8 413.74	
Train service........................	215.03	
Rental of equipment.................	522.79	
Miscellaneous material and labor....	2 028.98	
Transportation of contractors men...	46 736.96	
Transportation of equipment..........	73 483.36	174 267.72

Percentage of extras to contract price 13.84 per cent.

In this contract there were the following quantities:

Earth excavation, 4 097 881 cu. yd. at 20 and 22 cents...	$868 314.66
236 300 " " classified material..	137 589.38
4 334 181 cu. yd., at average 23.2 cents	$1 005 904.04
Added to this was overhaul........................	253 663.77
	$1 259 567.81

Thus the overhaul added to the cost 6 cents per cu. yd., or 25 per cent.

"Example 4.—In the construction of the Musconetcong tunnel of the Lehigh Valley Railroad, the contract cost, based on unit prices,

a list of which is given in Drinker's 'Tunneling' (page 1085), was \$883 938, whereas the actual final cost, including the payment of contractors' claims not settled until four years after the completion of the tunnel, was \$1 282 149, an increase of nearly 50% over the cost as reflected in the commonly accepted unit prices."

These few examples indicate clearly the danger of adopting arbitrarily, as a unit price for reproduction cost, some figure based on a contract price or an average of contract prices, without most thorough study of the results of actual similar work. Many other illustrations as to the effect of the several elements of cost on the final price of various classes of work into which labor largely enters, and in which the hazards of construction are great, might be cited. Enough has been said, however, in the opinion of the Committee, to emphasize the statement that in each case conditions must be examined to find out what elements of cost do enter into the unit price, and that each unit price must be supported, if supported at all, by actual costs of similar work under similar conditions.

Unit costs found by general inquiry of supplying companies, engineers, contractors, and others are rarely reliable because of the lack of full knowledge on the part of those furnishing the information concerning the character of the work and the specifications and conditions under which it is to be done, and because of the fact that they are not likely to make the detailed, intelligent study which might justify subsequent expression of opinion. Even competitive bids on detailed specifications may not furnish reliable figures. Recent actual final construction costs on the plant being estimated or on similar properties, located under similar conditions, furnish the safest criteria. All such data should be interpreted in the light of sound judgment and wide construction experience.

An examination of the tabulated bids of any large contract letting will disclose the unreliability of individual opinion. It must be borne in mind that such bids are based on identical plans and specifications and conditions. It is not at all unusual to find variations in bids on individual items varying from 15 to 40% to as much as 100% or more. In some cases the opinions of contractors, as expressed by their bids, may represent a proper figure based on wide experience and full knowledge of local conditions, but other bids may be in no wise representative, and be radically high or low.

To conclude the discussion of unit prices, the Committee is of the opinion that a rational sequence of construction should be followed in the reproduction of a property; and that rational assumptions should be made as to the manner of doing the different parts of the work, whether by the forces of the company or by contract. Unit prices, based where possible on the actual cost of doing similar work, in a

similar manner, under similar circumstances, should be determined by persons of experience and sound judgment.

If, on the basis of the assumed conditions, piecemeal construction is required, and if the most appropriate way of executing such piecemeal construction is by doing the work directly by the company's forces within the assumed periods of construction and development, then the cost of work done in this way should be used in determining the reproduction cost. If the assumed conditions indicate that other portions of the work could be done more economically by contract, then the unit prices should have as their basis the price which a contractor would charge for doing such work, but to this must be added all other elements of cost or expense to the owner which can be separately allocated.

The unit prices should be based on the normal average cost of work for a considerable period—say, 5 or 10 years—in order to give stability to the valuation, so that it may be used for a subsequent term of years. In the case of items which are steadily increasing or decreasing in value, the prices adopted should be normal for the time of the valuation.

Full consideration should be given to the time allowed for construction, and due weight given to climatic conditions and the effect of weather on the cost of the work.

The Committee emphasizes the necessity for full information from trustworthy sources as to the actual complete cost of doing similar work under similar circumstances. The greater the amount of such data, making possible the adoption of complete and correct unit costs, the smaller the amount of overhead percentages which are necessary for providing for proper total construction costs.

The Cost of Reproducing Land Holdings.

For the reproduction cost of land holdings the Committee will base its arguments and conclusions on the law as expressed by selected and apparently authoritative Court decisions, and on those results of attempts of public or private purchasers to acquire properties for public purposes which are of common knowledge to engineers and others having to do with such matters. Examples of some of these results, fortifying the arguments and conclusions of the Committee, will be given.

Lands not All of Similar Character.—Classes of Land.—Not all lands acquired by public service corporations fall under one class; there are radical differences, and it is essential that a proper classification of them be made in any valuation.

Three classes result from a consideration of the extent and character of the acquisition:

1.—The acquisition of a single whole parcel, which may be selected from among several available parcels.
2.—The acquisition of a number of whole contiguous parcels to form a tract of moderate size.
3.—The acquisition of a number of parcels, both whole parcels and parts of parcels, to form a continuous strip, such as a railroad right of way, or a large body, like a collecting or storage reservoir.

1.—Single or Detached Parcels of Land.—In many instances lands are acquired and used by public service companies, which are in detached parcels of ordinary size, not connected with the other lands owned or used in the conduct of the business. These lands are not acquired in response to a need for the particular parcel. Any parcel of the same or similar area, in the same general locality, would meet the requirement of the company nearly or quite as well. Examples of this class are seen in lands acquired for electric generating- or sub-stations, car barns, warehouses or material yards, gas plants or gas-holders, office buildings, and other similar uses.

It may be that location on a water-front, or a point of convenient access to side-track facilities, is a desideratum, but any one of several parcels, which meets those requirements in the vicinity, may serve the purpose. It would seem to be clear that in such cases the same general laws which regulate values of land for any other purpose in the immediate neighborhood would govern, and that the reproduction cost of the land would be fixed by the value of other lands used for general purposes, as shown by sales, asking prices, or in any other manner that is usual and proper.

Presumably, the public service corporation, in the same way as an individual seeking a factory site or residence, would have a fairly wide range of selection and would choose that tract which would meet the requirements and could be had at the most reasonable price. It is fair to assume that such purchases would be at substantially the market value of lands in the vicinity at the time of acquisition, and would be subject to the same increase or decrease in value as other near-by similar lands the values of which would be affected by the same causes.

Therefore, it would appear that the reproduction cost of such a holding as an ordinary lot, or a tract of not unusual size, which is entirely disconnected from other holdings, should be based on adjacent or near-by land values for general purposes, should include no severance damages, but should include a reasonable allowance for the costs of acquisition.

2.—Tracts of Land.—Tracts of land of considerable area, including a number of lots or blocks, offer a more difficult case, for, aside from any such expenses as vacation of streets or alleys, or other work done to bring the tract as a whole into a usable condition, there is likely to have been originally an element of enhanced cost, due to the fact that the demand for a large number of contiguous small parcels tends to enhance the price rapidly, and even in a district where a large part of the lands are for sale, the demand affects the price before all can be acquired. Usually, in the acquisition of such a body of land, made up of many small parcels, some owners will have to be dealt with who are unwilling sellers and who hold out for an extreme price, making necessary either condemnation, or the forced payment of a higher consideration than would ordinarily be the case. Any condition necessitating the purchase of a number of adjacent parcels and uniting them into one large tract suitable for a specific purpose tends to remove the transaction from the simpler first case and take away the free choice of sites. Such cases demand a much more careful study of costs, especially with reference to recent accumulation of property of the same kind.

It may be seen readily, for example, that the purchase of 50 or 60 lots from numerous owners may increase the price per lot far above the normal price under a demand for only one lot or a few lots. The immediate demand for all the lots may and usually does add materially to the cost of the whole. Later, the demand being supplied and ceasing, prices drop to the old level, so that a valuation based on later sales of neighboring lots would show less than original cost and less than any possible cost of reproduction at the time of making the estimate.

Although general land values will have an important bearing on the price, consideration based on actual experience in comparable situations should be given to the effect of the large and pressing demand.

It is argued that, in such a case as the one cited, actual original cost, and not reproduction cost based on present land values, would be ample allowance, especially as in many cases the actual original cost of the assembled tract would be considerably in excess of the present value of neighboring lots for general purposes. It would seem to be fair, however, in those cases in which the original cost of an entire assembled tract exceeded the total market value of all the separate parcels at the time the acquisition was commenced, to assume that, if general values of lots increase in the vicinity, the cost of reproduction of the tract acquired for a specific purpose should, as a general rule, increase *pro rata*.

Similar questions are raised where lands are acquired for the extension of an existing plant. In such cases, prices may be and sometimes are demanded and necessarily paid which are far above normal.

In the cases cited there may be some freedom of choice as to the exact lands, but the difficulties due to acquisition of numerous parcels will be encountered no matter which of several possible tracts is selected. The reproduction estimate should be based on the value of land in the vicinity, the figure adopted including the incidental costs of acquisition of private titles, severance damages, if there was any severance, and the cost of acquiring any rights requisite for the use of the tract as a whole, such as vacation of streets or alleys, and the purchase of leases. All recorded excess costs above a normal market value should be given due weight. Only thus will the present reasonable cost of reproduction be obtained.

3.—Connected Strips or Bodies of Land.—By far the greatest difficulty arises when required lands constitute a connected strip or body, and there is no option in the choice of lands, all of which must be acquired to form the required strip or body.

An example of this class is furnished by a steam or electric railroad right of way. Here, the lands are a narrow strip, not purchased in ordinary commercial units of 10, 20, or 40-acre tracts, or of lots or other subdivisions of a plat, but in small fractions of such tracts taken without reference to the effect on the remainder of the tract from which they were taken. The location is determined by topography and continuity of route, and may not be varied on account of the objections of a land-owner. All the right of way must be acquired.

Another example is that of flowage lands for a reservoir. In this instance, many entire parcels must be acquired, and unless a greatly excessive acreage is taken, many irregular fractions must be bought. Here, as in the railroad right of way, conditions of topography and continuity govern. It must be this particular land and no other, and all of it must be had.

All valuations of lands acquired for any use where all must be had, and no choice or option as to the selection is left the purchaser, must rest on the same general principles of valuation. The Courts have clearly established the general principles which govern the fixing of value of property condemned for public use.

All elements of value must be considered. The owner must be recompensed, not only for the value of the land taken, but for all damages or losses of value suffered by him on account of the taking.

Under the law interpretation of just compensation, there can be no doubt that in cases of water-works reservoirs, railroad rights of way, flowage lands, or other properties of like nature, where the lands are not necessarily in uniform parcels, and where part of the land is taken and part cut off and left, just compensation will include the value of the lands taken and the money equivalent of any damages suffered by the owner by reason of the taking. This is all value to the seller and represents what is taken from him.

It would seem that these same principles are applicable in the valuation of such property in making a reproduction estimate.

The Term "Just Compensation" as Defined by the Courts.—The Constitution prescribes that private property shall not be taken without just compensation. The rules governing the condemnation of private property have been thoroughly established by a long line of decisions. All elements of value must be considered. The owner must be recompensed, not only for the value of the land taken, but for all damages or losses of value suffered by him on account of the taking.

The terms, "compensation", "just compensation", "due compensation", etc., have been defined in many cases.

In Virginia & Truckee R. R. Co. *vs.* Henry, the Court said (8 Nev., 165):

"It is difficult to imagine an unjust compensation; but the word 'just' is used evidently to intensify the meaning of the word 'compensation'; to convey the idea that the equivalent to be rendered for property taken shall be real, substantial, full, ample; and no legislature can diminish by one jot the rotund expression of the constitution. So are all the decided cases. While courts have differed upon minor points, two of which the statute of this state settles, namely, the allowance for particular benefit derived from the construction of the railroad and the exclusion from the calculation of damages of the cost of necessary cattle guards and fences when the petitioner offers to construct, yet upon the great substantial underlying basis upon which only can arise a constitutional law for the taking of private property for public use—the absolute protection of the individual by just compensation—there has been, could be, no dispute."

In Pick *v.* Rubicon Hydraulic Co. (27 Wis., 445), the Court said:

"In the case of Bigelow *vs.* The Western Wisconsin Railway Co., decided by this court at the present term, it was held that 'just compensation' consists in making the owner good, by an equivalent in money, for the loss he sustains in the value of his property by being deprived of a portion of it; and that it includes not only the value of the portion taken, but also the dimunition in value of that from which it is severed. In establishing this rule, we followed the reasoning of this court in Robbins *v.* Milwaukee and Horican R. Co., 6 Wis., 636; in Snyder *vs.* Western Union R. Co., 25 Wis., 60; and in Welch *v.* Milwaukee and St. Paul R. Co., 27 Wis., 108; and adopted the doctrine of numerous adjudications by the courts of other states upon the same subject."

The cases cited show the general rule as to the taking of lands by condemnation. There can be no doubt that, in the case of a waterworks reservoir, a railroad, flowage lands, or other property of like nature, where the lands are not necessarily in uniform parcels, and where part of the land is taken and part cut off and left, any amount necessarily paid as just compensation or as damages is a cost which

cannot be evaded by the purchaser. It is value to the seller, reimbursing him for what has been taken from him. It is an actual cost to the purchaser which is properly chargeable to the capital account.

The reproduction cost, or present cost of acquisition, does not include elements of value arising subsequently to and because of the taking for utility purposes. It includes only such sums, for the land itself, as the several owners would be entitled to in case of present acquisition, plus costs of purchasing.

Same Elements Must be Considered in Valuation as in Fixing "Just Compensation."—It would seem to be clear from a study of all the cases that, in valuation of lands which partake of the nature of rights of way or flowage lands, the same principles should govern as in condemnation, and all such elements should be considered in valuation as are taken into account in fixing just compensation in condemnation. Thus, the cost to the utility at the time of acquisition is not to be substituted for, or taken to be, the equivalent of reproduction cost, because the land may have declined or increased in value since the acquisition. Nor does the source of the title, or of the funds used to acquire, affect the matter, because that which is paid for out of surplus, or that which is donated, is as much the property of the company owner as that acquired by the expenditure of other capital and payment of full value.

The market value of the land actually taken from an owner is one element of cost, the damage to remaining and adjacent lands of the same owner is another, the costs of all investigations of title, attorneys' or agents' fees, surveys, plans, and expenses, and all other costs in connection with the transaction, constitute another. All taken together make up the price of the property acquired, and, as a general rule, in the absence of mistakes, dishonesty, or extravagance, may be taken as the value at the time of investigation. As said in the Minnesota rate cases (page 451):

"It [the utility] would be free to stand upon its legal rights and it cannot be supposed that they would be disregarded."

Thus, the presumption is that the amounts in condemnation judgments are not excessive. And, as a general rule, in the case of acquisition by purchase, it may be assumed that the utility does not pay more than the owner is legally entitled to receive.

All these elements of value for which "just compensation" would be rendered in a condemnation, exist in greater or less degree and must be considered, whether the land was actually acquired by condemnation or by private purchase. It occasionally happens in the case of many corporations not having the right of eminent domain, such as hydro-electric power properties in some States, that the prices paid are excessive of necessity.

Market Value of Adjacent Lands, per Acre, Not Always Conclusive.—It must be remembered that general land values are based on sales where a willing seller deals with a willing buyer. In the case of farm lands, for example, a man who desires a farm in a certain locality has the choice between a number of pieces that are on the market. He may be satisfied with one 40-acre farm, but considers the price too high. He has the option of paying the price or taking another farm at a lower price. As has been said, the railroad or the water company has no such option, but must take that parcel and no other. Experience has shown that condemnation juries often fix a high price and that often it is better business judgment to pay as large a sum as the condemnation prices, in order to avoid the expenses of condemnation, the delay caused by the proceeding, and the feeling aroused in a community by litigation. It often occurs that contiguous lands have not the same availability or value as the lands acquired by a utility, and only when they are comparable can the market value of such lands be used as a basis for estimate.

From the nature of the strips of land acquired for public utilities, the compensation paid, when measured in terms of dollars per acre on lands actually taken, appears to be very high compared with the per acre price paid in sales of similar lands for general purposes.

For example, a railroad company condemned a strip of land, 100 ft. wide, across a tract containing approximately 40 acres, cutting it in two nearly in the middle. The strip taken was 1 600 ft. long and contained 3.65 acres, leaving 36.25 acres to the owner, divided approximately 20 acres on one side of the road and 16 on the other. The building of the railroad necessitated changing fields and drainage, introduced two farm crossings with gates to open and shut in perpetuity, and not only cut off a corner of an orchard, but introduced a fire hazard, as the stables were near the line.

All these considerations caused a jury to fix as compensation the sum of $100 per acre for land taken, which was a fair figure based on several recent sales, and the further allowance of $15 per acre as the damages to the remainder. The compensation, therefore, was, for land, $365, for damages, $545, a total of $910, to which was added acquisition and overhead costs in excess of $170, or a total cost to the company, exclusive of interest, of $1 080, or almost exactly three times the acreage price fixed by the jury.

Several purchases at private sale in the same county were at approximately the same figure.

In some of the early valuations, notably the State railroad valuations in Michigan, Wisconsin, and Minnesota, the attempt was made to establish the relation between sales to railroads and sales to individuals by a study of the record of actual sales. Based on these

studies, a system for fixing the cost of reproduction of railroad lands by the use of multiples applied to farm land values was adopted.*

The Michigan tax cases, in which this method of valuation was used, reached the Courts without any contention being raised as to the methods or results of the valuation, but on other issues. Hence, the question was not passed on. The Minnesota valuation of land by this method became an issue in the Minnesota rate cases, and the method was not approved by the Supreme Court.

The Minnesota Rate Case Decision.—In many respects the most important decision bearing on land valuation is that of Mr. Justice Hughes in the Minnesota rate cases. This decision is of such importance, and has had so many interpretations placed on it, that extended quotation from it appears to be desirable. The decision must be construed as a whole, and all parts of it bearing on the subject of land must be studied together, in arriving at a conclusion as to the exact meaning. (Simpson *et al.*, constituting the Railroad and Warehouse Commission of the State of Minnesota *v.* Shepard, 230 U. S., 352, *et seq.* (1912), Syllabus, page 355.)

"For fixing rates the basis of calculation of value is the fair value of the property of the carrier used for the convenience of the public." (Smyth *v.* Ames, 169 U. S., 466.)

"There is no formula for the ascertainment of the fair value of property used for convenience of the public, but there must be a reasonable judgment having its basis in a proper consideration of all relevant facts. * * *

"Assets and property of a carrier not used in the transportation business cannot be included in the valuation as a basis for rate-making.

"Property of a railroad company cannot be valued for a basis of rate-making at a price above other similar property solely by reason of the fact that it is used as a railroad, and increases in value over cost cannot be allowed beyond the normal increase of other similar property."

After setting forth the values allowed by the Master and the Court below for land in the Northern Pacific case, stating the contentions in the case, and quoting from Mr. Cooper's testimony at some length, in order to show how he arrived at his estimates of value, and after bringing out the fact that "market value", as used by Mr. Cooper, was intended to mean, not the value of land for general purposes, but what it would cost the railroad to acquire the land, the Court says:

1.† "In reviewing the findings, the court below reached the conclusion that 'the master in effect found that the cost of reproduction

* "The Valuation of Public Service Corporation Property", by Henry E. Riggs, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXII, pp. 59–64, inclusive. Discussion by the late W. D. Taylor, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LII, p. 359. Report of Mr. Dwight C. Morgan to Minnesota Railroad and Warehouse Commission.

† Paragraphs are numbered by the Committee for convenience in referring to them in discussion.

and the present value of the lands for the terminals in the three great cities, including therein all cost of acquisition, consequential damages, and value for railroad use which he allowed, was only about 30 per cent. more than the normal value of the lands in sales between private parties. He found the value of the lands outside the terminals to be only twice their normal value.'

2. "From our examination of the evidence we are unable to conclude that the excess stated may be thus limited. What is termed the normal value does not satisfactorily appear. It further will be observed —from the summary of valuations we have set forth in the margin— that the amount thus allowed in item 1 for lands, yards, and terminals, both in and out of the three cities ($21,024,562), was included in the total on which 4½ per cent. was allowed in item 30 for 'engineering, superintendence, legal expenses', and again was included in the total on which 5 per cent. was allowed in item 37 for 'contingencies', and, in addition, was included in the total on which 10 per cent. was allowed in item 39 for 'interest during construction'.

3. "These are the results of the endeavor to apply the cost-of-reproduction method in determining the value of the right of way. It is at once apparent that, so far as the estimate rests upon a supposed compulsory feature of the acquisition, it cannot be sustained. It is said that the company would be compelled to pay more than what is the normal market value of property in transactions between private parties; that it would lack the freedom they enjoy, and, in view of its needs, it would have to give a higher price. It is also said that this price would be in excess of the present market value of contiguous or similarly situated property. It might well be asked, who shall describe the conditions that would exist, or the exigencies of the hypothetical owners of the property, on the assumption that the railroad were removed? But, aside from this, it is impossible to assume, in making a judicial finding of what it would cost to acquire the property, that the company would be compelled to pay more than its fair market value. It is equipped with the governmental power of eminent domain. In view of its public purpose, it has been granted this privilege in order to prevent advantage being taken of its necessities. It would be free to stand upon its legal rights and it cannot be supposed that they would be disregarded.

4. "It is urged that in this view the company would be bound to pay the 'railroad value' of the property. But supposing the railroad to be obliterated and the lands to be held by others, the owner of each parcel would be entitled to receive on its condemnation its fair market value for all its available uses and purposes. (United States *v.* Chandler-Dunbar Water Power Co., decided May 26, 1913, 229 U. S., 53.) If, in the case of any such owner his property had a peculiar value or special adaptation for railroad purposes, that would be an element to be considered. (Mississippi, etc., Boom Company *v.* Patterson, 98 U. S., 403; Shoemaker *v.* United States, 147 U. S., 282; United States *v.* Chandler-Dunbar Co., *supra.*) But still the inquiry would be as to the fair market value of the property—as to what the owner had lost, and not what the taker had gained. (Boston Chamber of Commerce *v.* Boston, 217 U. S., 189, 195.) The owner

would not be entitled to demand payment of the amount which the property might be deemed worth to the company, or of an enhanced value by virtue of the purpose for which it was taken, or of an increase over its fair market value, by reason of any added value supposed to result from its combination with tracts acquired from others, so as to make it a part of a continuous railroad right of way held in one ownership. (United States *v.* Chandler-Dunbar Co., *supra*; Boston Chamber of Commerce *v.* Boston, *supra.*) There is no evidence before us from which the amount which would properly be allowable in such condemnation proceedings can be ascertained.

5. "Moreover, it is manifest that an attempt to estimate what would be the actual cost of acquiring the right of way, if the railroad were not there, is to indulge in mere speculation. The railroad has long been established; to it have been linked the activities of agriculture, industry, and trade. Communities have long been dependent upon its service, and their growth and development have been conditioned upon the facilities it has provided. The uses of property in the communities which it serves are to a large degree determined by it. The values of property along its line largely depend upon its existence. It is an integral part of the communal life. The assumption of its non-existence, and at the same time that the values that rest upon it remain unchanged, is impossible and cannot be entertained. The conditions of ownership of the property and the amounts which would have to be paid in acquiring the right of way, supposing the railroad to be removed, are wholly beyond reach of any process of rational determination. The cost of reproduction method is of service in ascertaining the present value of the plant, when it is reasonably applied and when the cost of reproducing the property may be ascertained with a proper degree of certainty. But it does not justify the acceptance of results which depend upon mere conjecture. It is fundamental that the judicial power to declare legislative action invalid upon constitutional grounds is to be exercised only in clear cases. The constitutional invalidity must be manifest, and if it rests upon disputed questions of fact the invalidating facts must be proved. And this is true of asserted value as of other facts.

6. "The evidence in these cases demonstrates that the appraisement of the St. Paul and Minneapolis properties which were accepted by the master were in substance appraisals of what was considered to be the peculiar value of the railroad right of way. Efforts to express the results in the terms of a theory of cost of reproduction fail, as naturally they must, to alter or obscure the essential character of the work undertaken and performed. Presented with an impossible hypothesis, and endeavoring to conform to it, the appraisers—men of ability and experience—were manifestly seeking to give their best judgment as to what the railroad right of way was worth. And doubtless it was believed that it might cost even more to acquire the property, if one attempted to buy into the cities as they now exist and all difficulties that might be imagined as incident to such a 'reproduction' were considered. The railroad right of way was conceived to be a property *sui generis,* 'a large body of land in a continuous ownership,' representing one of the 'highest uses' of property and

possessing an exceptional value. The estimates before us, as approved by the master, with his increase of 25 per cent. in the case of the Duluth property, must be taken to be estimates of the 'railway value' of the land; and whether or not this is conceived of as paid to other owners upon a hypothetical reacquisition of the property is not controlling when we come to the substantial question to be decided.

7. "That question is whether, in determining the fair present value of the property of the railroad company as a basis of its charges to the public, it is entitled to a valuation of its right of way not only in excess of the amount invested in it, but also in excess of the market value of contiguous and similarly situated property. For the purpose of making rates, is its land devoted to the public use to be treated (irrespective of improvements) not only as increasing in value by reason of the activities and general prosperity of the community, but as constantly outstripping in this increase, all neighboring lands of like character devoted to other uses? If rates laid by competent authority, State or national, are otherwise just and reasonable, are they to be held to be unconstitutional and void because they do not permit a return upon an increment so calculated?

8. "It is clear that in ascertaining the present value we are not limited to the consideration of the amount of the actual investment. If that has been reckless or improvident, losses may be sustained which the community does not underwrite. As the company may not be protected in its actual investment, if the value of its property be plainly less, so the making of a just return for the use of the property involves the recognition of its fair value if it be more than its cost. The property is held in private ownership and it is that property, and not the original cost of it, of which the owner may not be deprived without due process of law. But still it is property employed in a public calling, subject to governmental regulation, and while under the guise of such regulation it may not be confiscated; it is equally true that there is attached to its use the condition that charges to the public shall not be unreasonable. And where the inquiry is as to the fair value of the property, in order to determine the reasonableness of the return allowed by the rate-making power, it is not admissible to attribute to the property owned by the carriers a speculative increment of value, over the amount invested in it and beyond the value of similar property owned by others solely by reason of the fact that it is used in the public service. That would be to disregard the essential conditions of the public use and to make the public use destructive of the public right.

9. "The increase sought for 'railway value' in these cases is an increment over all outlays of the carrier and over the values of similar land in the vicinity. It is an increment which cannot be referred to any known criterion, but must rest on a mere expression of judgment which finds no proper test or standard in the transactions of the business world. It is an increment which in the last analysis must rest on an estimate of the value of the railroad use as compared with other business uses; it involves an appreciation of the returns from rates (when rates themselves are in dispute) and a sweeping generalization embracing substantially all the activities of the community. For an allowance of this character there is no warrant.

10. "Assuming that the company is entitled to a reasonable share in the general prosperity of the communities which it serves, and thus to attribute to its property an increase in value, still the increase so allowed, apart from any improvements it may make, cannot properly extend beyond the fair average of the normal market value of land in the vicinity having a similar character. Otherwise we enter the realm of mere conjecture. We therefore hold that it was error to base the estimates of value of the right of way, yards, and terminals upon the so-called railway value of the property. The company would certainly have no ground of complaint if it were allowed a value for these lands equal to the fair average market value of similar land in the vicinity, without additions by the use of multipliers, or otherwise, to cover hypothetical outlays. The allowances made below for a conjectural cost of acquisition and consequential damages must be disapproved; and in this view we also think it was error to add to the amount taken as the present value of the lands the further sums calculated on that value, which were embraced in the items of 'engineering, superintendence, legal expense', 'contingencies', and 'interest during construction.'"

Conclusions to be Drawn from the Minnesota Rate Case.—Careful study of this case seems to indicate that the Court did not intend to exclude from railway lands any of those elements of cost which necessarily must be met in their acquisition; on the contrary, it is distinctly stated that

"It is impossible to assume that the company would be required to pay more than its fair market value. It is equipped with the power of eminent domain. * * * It would be free to stand upon its legal rights and it would not be supposed they would be disregarded."

Thus, the Court makes the cost of acquiring by condemnation the test. The utility cannot claim any more in the reproduction estimate than would be paid were all the land to be condemned, giving the owners its fair market value for all available uses and purposes.

Another point that is strongly brought out is the fact that land valuation must be capable of proof by reference to known and established criteria and must not be based on speculation or hypothesis. Among the paragraphs quoted by the Court from Mr. Cooper's testimony, is the following:

"'Q. * * * There is nothing in any of your exhibits which will show, nor are you now prepared to state, the difference in what might be termed the normal, true, ordinary market value of the lands to the ordinary individual, and the sum which you have fixed as the market value to the railroad company if it were now compelled to purchase? A. That is correct.'"

Again, after discussing all the elements of value which would be allowable in case of condemnation, the Court says:

"There is no evidence before us from which the amount which would be properly allowable in such condemnation proceedings can be ascertained."

and, in the next to the last paragraph quoted:

"The amount of the fair value of the company's land cannot be satisfactorily determined from the evidence."

This decision must be looked on as sounding a strong note of warning against adding elements of value which are hypothetical, or increments which are based on generalization or speculation.

The adoption of a sweeping rule and its application, when "it cannot be referred to any known criterion", and has "no proper test or standard in the transactions of the business world", is not endorsed in this case. The problem in the valuation of lands of the class under consideration is to find such a rule as will apply, as will be capable of direct proof, and as will be supported by the standard of ordinary transactions in the business world and by actual experience in the buying of lands for similar purposes under similar conditions.

Although the decision does not seem to be capable of such an interpretation as would exclude any elements of value which would actually be paid for in acquiring the land, it does unequivocally bar from consideration any intangible values which would attach to the property by reason of its new ownership and new use. No hypothetical "railway value" is to be considered. The decision, throughout the discussion of land values, is full of references to these speculative elements of value and the impossibility of their determination by any known rules. It would appear to be clear that the Courts will not approve any attempt to attach to land values, in connection with the valuation of physical property, "a speculative increment of value, over the amount invested in it and beyond the value of similar property owned by others solely by reason of the fact that it is used in public service."

There is one element of loss to the owner which is not mentioned in the decision, but the Committee feels sure that the omission was not intended to deny the propriety of including the element, because, as seems to be indicated in Paragraphs 6 to 10, the Court satisfied itself with the decision that an attempt had been made to show "railway value", "what the taker had gained", for the land, that this was improper, and that there was no evidence submitted to show what the real value might be, and hence that other questions which might be pertinent were not considered. The element to which reference is made is that of damage to the remaining property by reason of the taking of a part of it—severance damages.

There is a long line of Court decisions in condemnation cases, and some State statutes which sustain the inclusion of this element of

cost wherever condemnation is necessary. It is not believed by the Committee that this decision is to be construed as arbitrarily excluding this element of just compensation, or value to the seller, where it would occur, and would be capable of proper proof.

Although the decision seems to exclude another item of cost to the company—namely, the costs of acquisition—the Committee believes that this exclusion is apparent rather than real, and that a proper estimate of the costs of acquisition, which should be made on a rational basis, the result of experience in or knowledge of similar purchases, would undoubtedly have been approved. The testimony before the Court seemed to include all the elements of cost over "fair value" as "fair value", and then to add to this and resulting sums successive percentages for engineering, etc., contingencies, and interest; all of which appealed to the Court as creating a purely hypothetical or conjectural value.

Therefore, in spite of the quite positive character of the latter half of Paragraph 10, the Committee believes that this wording, taken in connection with the last three sentences of Paragraph 3, the second sentence of Paragraph 4, the well-known interpretation at law of the term "just compensation", and the character of the testimony offered in the Minnesota rate case, does not exclude properly estimated "fair market value", "severance damage" where it would be incurred, or proper "costs of acquisition", from an estimate of the cost of reproduction, however the Court may regard any of these items when finally determining "fair value".

All three are certainly elements of the cost recognized by all persons who have had to do with the purchase of properties for public utilities whether privately or publicly owned. The Court contented itself with showing that the evidence before it was to sustain the value as what the taker would gain, not what the seller would lose; and that this is not a proper basis for cost of reproduction.

The Meaning of the Term "Market Value."—The words "market value" in the ordinary acceptance of the term mean the price of a commodity in the open market, the price at which it is bought and sold.

The market value of land for general purposes, as used in condemnation and similar cases, has been defined many times. As comprehensive and satisfactory a definition as any is that of the Supreme Court of Kansas, as follows (Kansas City, etc., Rd. Co. *vs.* Fisher, 49 Kans., 17):

"The market value means the fair value of the property as between one who wants to purchase and one who wants to sell, not what could be obtained for it under peculiar circumstances when a greater than its fair price could be obtained, nor its speculative value; not a value obtained from the necessities of another; nor on the other hand is it to be limited to that price which the property would bring when forced

off at auction under the hammer. It is what it would bring at a fair public sale when one party wanted to sell and the other to buy."

Mr. Justice Hughes fixed condemnation as the measure.

"It is impossible to assume * * * that the company would be compelled to pay more than its fair market value. It is equipped with the governmental power of eminent domain. * * * The owner of each parcel would be entitled to receive on its condemnation its fair market value for all its available uses and purposes."

What is the measure of damages in condemnation? What would the seller of the land be compelled to take as the fair market value? Lewis in "Eminent Domain", Section 463, states:

"*Measure of damages when entire tract is taken.* This case presents but little difficulty, and, so far as we have observed, there is no difference in the authorities as to the proper measure of damages. A fair equivalent for any entire piece of property is its value in money."

Also, in Section 464:

"*When part is taken, Just Compensation includes damages to the remainder.* Upon this point there is entire unanimity of opinion. The constitutional provision cannot be carried out, in its letter and spirit, by anything short of a just compensation for all the direct damages to the owner of the lot, confined to that lot, by the taking of his land. The paramount law intends that such owner, so far as that lot is in question, shall be put in as good a condition, pecuniarily, by a just compensation, as he would have been in if that lot of land had remained entire, as his own property. How much less is that lot, and its erections thereon remaining, worth to the owner, as property to be used or leased or sold the day after the part was taken, to be used for the purposes designed, than the whole lot intact was the day before such taking (Bangor & Piscataqua R. R. Co. *vs.* McComb, 60 M. E., 290). In considering damages to the remainder however, the whole remainder must be taken into account. If part is damaged and part benefited, the question will be whether the whole is worth less than before the taking."

The same use of the word "just" is to be found in nearly every State Constitution wherein "just compensation" is used to express the measure of damages for taking of property under the right of eminent domain.

The value to be used, therefore, is the fair market value of the property taken and the damages to that not taken, and "just compensation" shall take into account all elements of value heretofore discussed.

The Committee is of the opinion that in estimating cost it is not error to consider each parcel originally acquired, and to attach to it such reproduction cost as would be fixed in condemnation, including severance damages, where severance would actually occur, and that the reproduction cost so found should be accepted as significant. To

assume arbitrarily a rule of valuation, based on the use of hypothetical multiples, and apply it to the entire acreage of lands in a State cannot be sustained. The failure to point out what proportion of lands bear severance damages, and the failure to support by actual recent costs or actual recent experience in the acquisition of similar lands, and the further failure to indicate the relation existing between the price per acre measure when applied to utility lands, many if not most of which have a large element of consequential damages, and the price per acre measure applied to entire tracts taken or tracts sold for general purposes, is likely to be serious and defeat the object of the valuation.

Value to Owner and Taker.—The Element That Must be Excluded in Valuation.—Turning to Boston Chamber of Commerce *v.* Boston (217 U. S., 189, 195), we find the origin of the expression of the quoted paragraph, "as to what the owner had lost, and not what the taker had gained", and the facts in that case clearly indicate that in condemnation cases the inquiry must be, "What has the owner lost?"

It is somewhat difficult to understand that the taker may fairly obtain something with which the owner does not part, but, taken in connection with Paragraphs 478 and 479 of Lewis on "Eminent Domain", and with decisions heretofore quoted, it seems to be quite apparent that Mr. Justice Hughes made what he meant sufficiently clear when he said:

"The owner would not be entitled to demand payment of the amount which the property might be deemed worth to the company, or of an enhanced value by virtue of the purpose for which it was taken, or of an increase over its fair market value, by reason of any added value supposed to result from its combination with tracts acquired from others, so as to make it a part of a continuous railroad right of way held in one ownership."

This language harmonizes with the well-settled principles set forth by Lewis, and shows that there may be something gained by the taker that is not properly a part of the damages which the owner sustains. This additional value is not properly to be included in the reproduction estimate.

The subject is gone into at some length in U. S. *v.* Chandler-Dunbar (229 U. S., pages 79-81), where a strategic value was claimed for certain property. Therein, the Court said:

"That the property may have to the public a greater value than the fair market value, affords no just criterion for estimating what the owner should receive. It is not proper to attribute to it any part of the value which might result from a consideration of its value as a necessary part of a comprehensive system of river improvement which should include the river and the upland upon the shore adjacent. * * * A 'strategic value' might be realized by a price fixed by the necessities of one person buying from another, free to sell or refuse as the price

suited. But in a condemnation proceeding, the value of the property to the Government for its particular use is not a criterion. The owner must be compensated for what is taken from him, but that is done when he is paid its fair market value for all available uses and purposes, Lewis, Eminent Domain, 2d Ed., Sec. 706; Moulton *v.* Newburyport Water Co., 137 Mass., 163, 167; United States *v.* Senfert Bros. Co., 78 Fed. Rep., 520; Alloway *v.* Nashville, 88 Tenn., 510, 514; United States *v.* Honolulu Co., 122 Fed. Rep., 581."

The Committee interprets the decision of the Court to support quite clearly the contention that all elements of value and damages to the seller considered in condemnation must be considered in valuation, but that special values due to increased earning power by reason of a new use are not approved in these decisions. This feature is especially emphasized in City of New York *vs.* William Sage, Jr., (229 U. S., 372).

In this case, the Commissioners appointed by the City reported that:

"The sum of $7 624.45 for lands and buildings and the further sum of $4 324.45 for reservoir availability and adaptability being a grand total of the sum of $11 948.90 is the sum ascertained and determined by us * * * to be paid to the owners of and all persons interested in said land for the taking of the fee thereof, designated * * * as Parcel 733."

The report was confirmed by the Circuit Judge (190 Fed., 413) and by the Circuit Court of Appeals (124 C. C. A., 251, 206 Fed., 369) but was reversed by the U. S. Supreme Court, which said (229 U. S., 372):

"Upon an inspection of the record it appears to us, as the language of the Commissioners on its face suggests, that their report does not mean that the claimant's land had a market value of $11 948.90—that it would have brought that sum at a fair sale—but that they considered the value of the reservoir (site) as a whole and allowed what they thought a fair proportion of the increase, over and above the market value of the lot, to the owner of the land, subject to the opinion of the Court upon the point of law thus raised. * * * But the only explanation of the separation of items by the Commissioners is that they were not prepared to say that the market value of the lot was $11 948.90, seeing that the claimant bought it a few days before for $4 500, but that they thought the additional value gained by the City's act should be taken into account and shared between the City and the owner of the land—a proposition to which we cannot assent (Minnesota Rate Cases, 230 U. S., 352, 451; McGovern *v.* New York, 229 U. S., 363, 372)."

* * * * * * *

"The decisions appear to us to have made the principles plain. No doubt when this class of questions first arose it was said in a general way that adaptability to the purposes for which the land could be used most profitably was to be considered; and that is true. * * * But it is to be considered only so far as the public would have considered

it if the land had been offered for sale in the absence of the City's exercise of the power of eminent domain.

"The fact that the most profitable use could be made only in connection with other land is not conclusive against its being taken into account, if the union of the properties necessary is so practicable that the possibility would affect the market price. * * * But what the owner is entitled to is the value of the property taken, and that means what it fairly may be believed that a purchaser in fair market conditions would have given for it in fact—not what a tribunal at a later date may think a purchaser would have been wise to give, nor a proportion of the advance due to its union with other lots.

"The city is not to be made to pay for any part of what it has added to the land by thus uniting it with other lots if that union would not have been practicable or have been attempted except by the intervention of eminent domain.

"Any rise in value before the taking, not caused by the expectation of that event, is to be allowed, but we repeat, it must be a rise in what a purchaser might be expected to give."

* * * * * * *

"The enhanced value of the land as a part of the Ashokan Reservoir depends on the whole land necessary being devoted to that use. * * * If the parcels were not brought together by a taking under eminent domain, the chance of their being united by agreement or purchase in such a way as to be available well might be regarded as too remote and speculative to have any legitimate effect upon the valuation."

This case well illustrates the fact that in condemnation proceedings the owner is not entitled to the enhanced value of the land which comes to it as a part of the enterprise for which it is taken; that is to say, the additional value gained by the company's act of taking the land and combining it with other parcels should not be taken into account, and the owner is not entitled to participate in such additional value so gained. The company is not bound to pay any part of what it adds to the land by uniting it with other tracts. In determining the reproduction cost—what the owners are entitled to receive—adaptability to the purposes for which the land can be used most profitably may be considered, but only so far as the public would have considered such adaptability if the land had been offered for sale in the absence of the company's exercise of the power of eminent domain. The available uses and purposes referred to may not properly include any more than what it may be fairly believed a purchaser under fair market conditions would pay for the land in advance of its union with other lots for more profitable use. Any value which exists before the taking of the land, and which is not caused by the expectation of that event, is to be allowed.

Normal Cost of Public Utility Lands as Compared with General Land Values.—As has already been pointed out, sales of land for

general purposes are made under conditions which are very different from those that prevail in the case of sales for railroad or reservoir lands. In one case, the sale is of the entire parcel, both parties to the transaction being willing parties, the buyer being free to take or leave the bargain. In the other case, the purchaser must take this particular parcel or part thereof and no other. He may condemn, but if he takes only a part, he must include the element of severance and other damages in his price. These considerations lead the Committee to the conclusion that fair comparison can only be made with similar purchases, that is, railroad land costs for inclusion in a valuation by the reproduction method must be determined by a study of railroad purchases of lands of the same class, in the same locality. It may be that in certain districts the cost of lands for railroad right of way exceeds little, or not at all, the cost of lands for farming or other general purposes, while a few miles away the development of the country is such that very heavy severance damages will be incurred, thereby increasing the resulting cost per acre to several times that of the general purpose land. It devolves on the evaluator, therefore, to support his estimate by actual history as to the extent of inclusion of damages, and by actual recent costs of like accumulations of property in the same or contiguous territory or in territory where all general conditions are similar.

That, as a general rule, a right of way for a railroad or a body of lands acquired for a dam or reservoir does cost more per acre or square foot than other lands is clearly shown by a study of records of actual costs of such tracts.

Professor David Friday, in making the land valuation of the Pere Marquette Railroad, in Michigan, cites several instances of land purchases, as follows:

(1).—The right of way from Greenville to Stanton, purchased in 1900, cost $22 435. This includes several $1 considerations and does not include such costs of acquisition as services of real estate agents, registration fees, legal and recording fees, and other similar items of expense. The value of this record, on the basis of contiguous lands, would be only $6 738, manifestly an absurdly low figure in view of the fact that land in this district has increased in value more than 60% since the date of purchase.

(2).—The right of way from Belding to Lowell, purchased at various times between 1892-1900, cost $32 518. The present value, on the basis of adjoining lands, is $13 136. Here, also, the increase in value has been large.

(3).—The right of way from Oak to Delray, purchased in 1891-1892, cost $191 013. The present value, on the basis of adjoining lands, would be $121 120. The proximity of this land to the City of Detroit has increased general values by more than 100% since the acquisition of the right of way.

(4).—The land for the right of way for the new track at New Buffalo, consisting of 199 acres, was purchased in 1911 at an average cost of more than $185 per acre. This is at least three times the unit value of adjoining lands.

The following, also cited by Professor Friday, serve as further examples of the cost of railroad rights of way in various locations and under various conditions:

The Benton Harbor-St. Joe Interurban Road, from Benton Harbor to Coloma, Mich., a distance of 12 miles, bought, in 1910, 100.46 acres for its right of way at an average cost per acre of $267.30. This was bought through a territory which desired the road and in which land was worth from $60 to $100 per acre.

The Milwaukee, Sparta and Northwestern Railway in the State of Wisconsin purchased the 5 127 acres in its right of way and station grounds for $1 129 531. The market value of these lands on the basis of values of adjoining lands was $361 015, or less than one-third the amount actually paid therefor.

The Chicago, Burlington and Quincy Railway bought, some years ago, land in the City of Moline for $112 000. The market value of these lands, as estimated on the basis of adjoining values, was $66 600.

The "Soo" line paid for 3 460 acres in Wisconsin, purchased in extending its road from Glenwood north to the State line and from Thief River Falls west to the State line, the sum of $190 950. The value per acre of land in the immediate vicinity as estimated by the Wisconsin Tax Commission was $19.30; the price paid by the Railroad Company was $55.20, or 2.85 times the ordinary value.

Purchases for the Illinois Central through Mower and Freeborn Counties in Minnesota some years ago, amounting to 228 acres, cost the Railroad $125 per acre, while the adjoining lands were estimated by the Minnesota Railroad and Warehouse Commission as having a value of $49 per acre.

The Hastings and Northwestern Railroad Company, a subsidiary of the Union Pacific Railroad, purchased its right of way between August, 1912, and May, 1914, at a cost of $221 355.06. The value of this land, on the basis of unit values of adjoining land was $96 729.

In 1903, an extended series of investigations of actual considerations paid by railroads for rights of way for new lines, changes of line, and for lands for widening right of way, were made by Mr. Van Ranst Pond and H. E. Riggs, M. Am. Soc. C. E.

These investigations were supported by a large mass of testimony given by registers of deeds, land owners, and others, in the Michigan tax cases. There are very few condemnations in the many hundreds of transfers investigated. Some typical examples of these data follow:

The Jackson and Battle Creek Railway was an electric interurban line, partly paralleling the highways, and for a number of miles being parallel with and adjoining the Michigan Central right of way—all country lands; average considerations to owners in Jackson County, $239.53 per acre; in Calhoun County, $218.74 per acre. Farm land values in these counties range from $60 to $100 per acre, with $75 to $80 per acre as a liberal average.

In Monroe County, Michigan, several lines of road have been built since 1900. This is good farming land worth from $80 to $100 per acre. Considerations (average for the entire County) were paid for railroad lands as follows: Flint and Pere Marquette, $215.21; Toledo and Monroe (electric), $461.13; and the Detroit and Toledo Shore Line, $262.49.

The Grand Trunk Railway made certain changes of its lines near Flint and near Battle Creek, which involved in each instance building several miles of new line. This was far enough away from the old line to get out of the same farms and, except at the extreme ends, there were no complications due to crossing lands already cut. There were no condemnations. The line near Flint, in Genesee County, was entirely across good farm land worth from $100 to $115 per acre. The average paid per acre was $337.56. West of Battle Creek, in Calhoun County, the land was sandy and not high-class, and worth from $60 to $85 per acre. The average consideration was $491.13 per acre. In neither case were values affected by proximity to the cities, as there was no plotting of new additions near the city nor of either cut-off.

In 1896, the Ann Arbor Railroad built a new main line 10 miles north in Washtenaw County. This line left the old line about 3 miles north of Ann Arbor and was several miles west of the old road. It was wholly in farming lands, part of poor quality. Values ranged from $50 to $90 per acre, averaging about $75. The considerations averaged $285 per acre.

The foregoing examples are only a few of the many investigated in Michigan. In these, the railroad lands, no matter how acquired, cost

from two and one-half to six times as much as general lands, due, doubtless, in great measure, to the amount of severance damages paid by the companies, but which elements of cost were not segregated in the work in Michigan.

In none of the examples cited are costs of acquisition or overhead cost included.

Among the illustrations presented by the railroads to the Interstate Commerce Commission in 1915 was a statement showing, for a number of roads in several States, the actual cost of recent acquisitions of railway lands. This statement includes purchases on a total of more than 465 miles of line, and is summarized as follows:

Miles of line.	Total purchase, exclusive of costs of acquisition.	Bare land value, based on general values.	Percentage of land value to total cost.	Other elements of cost.	Percentage of other elements to total cost.
Right of way, 465.4.	$7 868 213	$3 857 783	49	$4 009 831	51
Yards and terminals.	2 005 158	1 144 774	57.2	856 384	42.8

These figures indicate so clearly that railroad purchases exceed purchases for general purposes that it would appear, with a proper presentation as to the percentages of the total acreage affected by other elements of cost, and proper support by reference to actual recent railroad costs under conditions similar to those under investigation, that the proof might be considered to be convincing as to the relation of actual costs to general values of lands.

That lands belonging to other classes of utilities present the same relation to general lands is more difficult of exact illustration on account of the scarcity of reliable records.

Certain records are available, showing the considerations paid for lands and the amounts paid for damages and incidental costs other than land in connection with the acquisition of lands.

New York City—Catskill Water Supply—Cost of Lands.*

Direct cost of 21 327 acres........	$10 699 946;	average	$509	per	acre
Interest (actual)................	1 648 801	"	78	"	"
Indirect and consequential damages.	294 801	"	14	"	"
Fees, legal, and sundry expense....	4 188 795	"	200	"	"
Total cost of lands........	$16 808 344;	average	$801	per	acre
Excluding interest.........			$723	"	"

The cost of acquisition, or overheads, excluding interest, aggregates 39.26 per cent.

* Based on Board of Water Supply figures of December 31st, 1914, litigation still pending as to value of 345 acres.

An analysis of this figure is of great interest as showing the same wide range between cost of land and expenses that occur in railroad lands.

Division of work.	Acres.	Cost of land per acre, award.	Expenses per acre.	Expenses, percentage of land cost.	Total per acre cost.
Ashokan Reservoir ...	15 221	$ 243	$ 155	61.41	$ 398
Northern Aqueduct...	1 637	470	428	91.08	898
Kensico Reservoir....	3 182	742	404	53.17	1 146
Hill View "	163	8 796	3 871	44.01	12 667
Southern Aqueduct...	957	1 987	787	39.66	2 774
City Aqueduct, 90 acres owned by city (bought)	76	6 585	962	15.03	7 547

A recent case in Michigan is very interesting, as throwing light on the cost and value of lands for flowage purposes.

A power company was organized to take over a tract of 17 000 acres of land on the Sturgeon River and build two hydro-electric plants. In 1911, the Duluth, South Shore and Atlantic Railway valuation placed the company's right of way in these counties (Houghton and Baraga) at from $25 to $45 per acre for country lands near the proposed site of the reservoir (about 2 to 5 miles distant). The State's attorney contended for values of from $5 to $10 per acre. Actual land sales throughout that part of the country occupied by reservoir and railroad had ranged from $2 to $10 per acre plus the value of the timber on the lands, or an average, land and timber, of about $12. Under the law, the power company applied to the Michigan Railroad Commission for authority to issue stock and bonds. The opinion, by Commissioner Lawton T. Hemans, is dated June 11th, 1913, and is in part as follows:*

"We believe that the lands described in the application herein should be capitalized at their fair market value, as represented by their initial cost, plus reasonable compensation for the time, energy, and ability bestowed in their acquisition, for the risk involved, and for the use of the capital invested during the interval that must elapse between the inception of the project, in carrying forward negotiations and purchases of distinct parcels, and their final utilization as an assembled whole. It may be contended that the various elements which it is suggested should form the basis of the capitalization allowed for lands and flowage rights are, except as to initial cost, as indefinite as capitalization computed upon any of the bases which the Commission rejects, but the Commission is persuaded that with the various elements stated, disproportion between them, if any exists, becomes more apparent with correspondingly greater certainty in arriving at correct values.

* Northern Michigan Power Company, Orders and Opinions, Michigan Railroad Commission, Vol. 2, No. 1, p. 25.

"It is not to be understood from the foregoing that the Commission holds that the initial cash payment for lands of the character involved is to be considered, of necessity, the all controlling factor in the fixing of their value for purposes of capitalization. Cases can be readily imagined where the cash cost of the physical property embraced in the lands and flowage rights was the least important of the factors enumerated. Indeed, the tract of land under consideration partakes strongly of this character. It is located in a comparatively undeveloped portion of the State, although in close proximity to the copper mining district of the State and possessed of some timber value, the physical features of the greater portion of the tract are such as to make it unsuited for agricultural purposes, compared with like areas alike suitable for water power development in other and more populous districts, the market value of the land is markedly less. The record does not disclose the exact cost of the assembled lands, although it does appear that they have been acquired at prices ranging from ten to one hundred and seventy dollars per acre, and that more than thirty thousand dollars was expended for lands at the last named sum. We are satisfied, from the record, that the sum of five hundred thousand dollars would amply cover the cash outlay for the purchase of the lands. But it appears that the work of acquiring the titles has been in progress since 1902, a period of more than ten years. If interest upon the real estate investment be allowed at six per cent. for half the time, which would seem to be just, it represents the sum of one hundred and fifty thousand dollars. The extended area of the lands necessary for this development have required, as the record discloses, the making of several surveys, the prosecution of legal proceedings, and extended negotiations with more than one hundred separate owners of distinct parcels, who have been found as widely scattered as the boundaries of the Union. Under the laws of this State, the powers of eminent domain are not accorded corporations which seek to develop hydraulic utilities. The last description of land necessary for the purposes of the enterprise must be acquired by purchases before the project is assumed, and while the element of risk involved in the ultimate purchase of so large a body of lands, held under such diversity of ownership, is difficult to estimate in dollars and cents, it is still a risk that is very real, and which enters materially into the value of the property acquired."

The testimony in this case shows that the lands varied in cost from \$10 to \$170 per acre, averaging about \$30. This was more than two and one-half times the average price per acre of lands sold in ordinary tracts. The costs of acquisition, allowing a moderate per diem for the actual time of the promoter plus the expense, were equal to the consideration paid to owners of land.

The examples cited are not exceptions. They are typical of all the cases which have come to the attention of the Committee. There is no general relation between the normal cost of lands acquired for railroad or reservoir purposes, and the market value of farm lands, or other general purpose lands, which can be considered fixed and definite.

Such a relation, however, may be established for limited districts. No rule can be formulated or multiple determined on, which can be universally applied, or even generally applied in any one State.

There have been, in the past, instances of the construction of railroads in timber tracts, or in the western prairie States, in advance of settlement, where the benefits to be derived from the line equalled or in cases far outweighed any damages; and, in such cases, it is easy to conceive that the price paid for the land would not greatly exceed the general average value of lands in the district.

Such conditions rarely exist in an old settled community. For many years the conditions prevailing in all such communities have made the normal cost of railroad and reservoir lands higher when the attempt is made to compute them on the basis of a price per acre.

Costs of Acquisition.—To What Extent Includable in Valuation?—The Interstate Commerce Commission in its classification of Investment in Road and Equipment, effective July 1st, 1914, includes as Items of Expense relating to land the following:

Abstracts
Appraisals
Arbitrators in condemnation cases
Commissions paid to others
Condemnation expenses including Court costs and special counsel fees
Damages to property of others
Deferred payments for right of way
Ditches for waterways when part of consideration
Judgments and decreed costs to clear or defend titles
Notarial fees
Plats
Premiums on condemnation bonds
Recording deeds
Payments for relinquishments of cattle passes and other rights
Removal and relocation of buildings and other structures not purchased
Rent of land when part of consideration for purchase
Right-of-way agents' compensation when engaged solely in acquiring right of way
Taxes accrued and assumed at the time of purchase.

Every one of these items is a necessary expense, not all incurred in connection with every parcel, but every parcel involving some of them, and all are chargeable to capital account as a legitimate cost.

The amount is considerable, in some cases a very large percentage of the purchase price of the parcel of land, but it is somewhat difficult to compute, for when it is reduced to a per acre basis or a percentage of cost basis it is extremely variable. The cost of condemning, or acquiring by purchase, a small fragment of land one-tenth of an acre in area may be as great as the cost of similarly acquiring a farm of many acres.

Examples of actual cost of acquisition of lands are of value as showing the extreme variations in percentage and per acre rates of such costs.

Land Purchases of the Buffalo, Rochester and Pittsburgh Railway.

Year ending June 30th.	No. of parcels.	Total acres.	Consideration for land.	Total costs of acquisition.	Cost of Acquisition: Percentage of consideration.	Per acre.	Per parcel.
1910........	35	165.789	$20 086	$5 828	2.9	$35.30	$166
1911........	16	58.694	16 604	1 521	9.1	26.00	95
1912........	29	60.732	33 506	1 718	5.1	26.50	59
1913........	63	109.705	73 469	3 486	4.7	31.70	55
1914........	24	28.730	50 292	3 677	7.3	126.40	153
Total and average.	167	423.646	$193 958	$16 231	8.38	$38.31	$97

These variations in costs of acquisition in percentages from less than 5 to 29, in cost per acre from $26 to $126, in cost per parcel from $55 to $166, are such as to show the necessity of careful investigation of varying local conditions before fixing the estimated amounts.

Land purchases of the Chicago and Northwestern, on one of its new lines, show ratios as follows: 3 620.41 acres; land consideration, $594 169; expense, $72 685; being 7.62%, or $20 per acre.

Statistics presented by Mr. Thomas W. Hulme, in the argument recently held before the Interstate Commerce Commission, show purchases by twenty different corporations for forty-five different pieces of construction. The percentages vary from a minimum of 0.86 to a maximum of 38.4.

Total consideration, all lines, $8 389 730.

Costs of acquisition, $452 656, average 5.4 per cent.

Water-works properties afford an illustration of a class of properties carrying a high cost of acquisition. This is shown by the land costs of the New York City Catskill water supply.* The whole matter may be briefly summarized, as follows:

Amount of awards for land, including payments for land purchased......	$10 669 946	
Awards for indirect damages.........	135 007	
Estimated awards for land and damages during 1915, proportionate part of $500 000	323 000	
Total payments for land and damages.............		$11 127 953

* Information furnished and arranged by Allen Hazen, M. Am. Soc. C. E., from records and published reports and with the aid of engineers of the Department.

Brought forward		$11 127 953
Expenses of acquiring land not including interest, as per Auditor's report	$4 188 795	
Do. in connection with damages awards	159 794	
Do. in connection with estimated awards during 1915, proportionate part of $500 000	127 000	
Total expenses		$4 475 589
Sum, being the cost of land, with expenses of acquiring it, but not including interest		$15 603 542
Interest on awards allowed by Commissioners and included in the Auditor's report, as part of the cost of land	$1 648 802	
Estimated interest on awards allowed for 1915, proportionate part of $500 000	50 000	
Total interest on awards		$1 698 802
Total actual payments for property to January 1st, 1916, including an estimate of $500 000 for payments in 1915		$17 302 344
Cost of carrying, after acquiring, up to the time when the system is to be put in service, taken as January 1st, 1916:		
Taxes paid	$216 534	
Taxes estimated for 1915	25 000	
Interest on amounts paid to January 1st, 1916, at 4.15%	3 746 652	
Total carrying charges		$3 988 186
Total cost of land and damages, with carrying charges up to date of first use of property, January 1st, 1916		$21 300 530

Calculating the percentages corresponding to these figures, it appears that the expenses of condemnation amounted to 40.1% of the awards and costs; that the interest on the awards allowed by the Commissions and included by the Auditor as part of the cost of the

land amounted to 10.85% of the awards and expenses; that the taxes paid by the city amounted to 1.5% of the cost of the preceding items; and that the interest on the various payments, from the dates of the payments until the property is put into use on January 1st, 1916, will amount to 21.3 per cent.

As a result of all these charges, the cost of the land to the city, with carrying charges to the date of first use, is 91.3% greater than the purchase prices and awards. In other words, the overhead charges on the land are 91.3 per cent.

The expenses of acquiring land as stated by the Auditor, in the sum of $4 188 795, are given below.

This particular case represents the acquisition of land by a city under a law which proved in its execution to be unusually burdensome. It is of value for illustrative purposes, on account of the prominent character of the work and the detail as to costs.

The total costs aggregated 39.26% of the purchase price, and were:

		Per cent.
Advertising	$433 946.46	4.16
Commissioners' fees	1 062 498.72	9.96
Expenses of Commissioners	79 898.40	0.75
Stenographers and clerks	62 606.70	0.59
Special counsel fees	358 679.20	3.36
Special counsel expenses	27 493.06	0.26
Obtaining orders	8 375.00	0.08
Closing title	1 370.00	0.01
Counsel fees on appeal	3 275.00	0.03
Costs on appeal	4 499.97	0.04
Searching titles	211 138.64	1.98
Preparing abstracts	125 312.50	1.17
Appraisers' fees	482 512.53	4.52
Appraisers' expenses	5 792.72	0.06
Rent of New York office	26 269.40	0.25
Stenographers' services and printing testimony	265 684.24	2.49
Counsel fees of parcel owners	384 405.99	3.60
Expenses and disbursement of parcel owners	261 275.36	2.45
Engineering salaries and expenses	373 760.65	3.50
	$4 188 794.54	39.26

Another detailed statement regarding the acquisition of land by a State commission, under a law which was not burdensome, is afforded by the experience on the Metropolitan Water-Works of Massachusetts. In this case the principal acquisition of land was for the Wachusett

Reservoir, the construction of which was not started until several years after other portions of the work were begun. The policy was followed, therefore, of acquiring this land as it could be obtained by negotiation, without resorting to condemnation except in special cases. Much of the land was acquired in this way, considerably in advance of the needs of the work, at a much lower price than it would have been obtained by condemnation, but with an increase in the charges to taxes and interest during construction. From the accounts of all real estate purchased, from the initiation of the work in 1895 to December 1st, 1909, the following summary is obtained:

Total paid directly for real estate, including mill properties and water rights acquired by negotiation		$3 390 723
Awards for real estate condemned, including interest to the date of payment............		170 446
Total direct payments for real estate...........		$3 561 169
Legal and expert services, including conveyancers, experts, appraisers, and court expenses, in acquiring above real estate, exclusive of counsel fees.	$179 944	
Estimated proportion of total administration expenses attributable to real estate	60 000	
Engineering expenses are shown by the accounts to amount to $83 582 for the Wachusett Reservoir alone. Assuming that other real estate acquisition would require the same percentage of engineering expenses, the total would be................	104 700	
Estimated expenses for counsel in real estate cases, charged to the general expenses of the State, and, therefore, not included in the water-works accounts	20 000	
Estimated expenses for financing and financial officers, attributable to real estate and charged to the general expenses of the State and, therefore, not included in the water-works accounts	20 000	
Total cost of acquisition.....................		$384 644

Brought forward	$384 644
Total cost of real estate, exclusive of taxes and interest during construction	3 945 813
Taxes during construction	68 182
Interest during construction on Wachusett Reservoir, real estate alone, on the basis of 5% compounded annually, would have amounted to $957 000, or 31% of the expenditures for this real estate, including incidental expenses, to the time when the reservoir was first operated. It is estimated that the interest during construction on other real estate would have increased this sum to	1 000 000
Total cost of real estate	$5 013 995

Calculating the percentages corresponding to the different figures, it appears that the incidental expenses of acquiring the real estate amounted to 10.8% of the direct payments for it; that the taxes paid during the construction of the works amounted to 1.9% of the direct payments; and that the interest on the various payments, from the dates of the payments until the property was put in use, on a 5% basis, would have amounted to 28.1% of the direct payments.

As a result of all these charges, the cost of the real estate, with overhead and carrying charges to the date of the operation of the property, is 40.8% greater than the direct payments for it.

The incidental expenses of 10.8% previously given may be subdivided as follows:

	Amount.	Percentage.
Legal and expert expenses, including counsel fees	$199 944	5.62
Administration	60 000	1.68
Engineering	104 700	2.94
Financial expenses	20 000	0.56
Totals	$384 644	10.80

The records of the Metropolitan Water-Works show the relation between the value of the real estate of the Wachusett Reservoir, exclusive of mill property, for general purposes, and the sums which were paid for it.

Before deciding on the project, an estimate of cost of the required real estate was made. To obtain a basis for this estimate, local experts were secured in each town, who went over all the lands, parcel by parcel, appraising the value of land and buildings separately. Their instructions were to value the property very liberally, and the results

obtained were much above its value as determined by sales which had been made about that time. Some of the experts owned property which would be taken for the reservoir. The assessed valuations in this district are supposed to be well up toward the full value of the property, but the value fixed by the experts was one and three-quarter times the assessed value of the property. As a result of the appraisal by the experts, the aggregate valuation obtained was, as follows:

Land, 4 772 acres	$244 000	
Buildings	453 000	$697 000

The cost of acquiring the same property, exclusive of overhead charges, was $1 182 000, equal to $485 000, or 69% in excess of the original liberal appraisal of the value.

It is to be noted that this is a case where the appraised general value of the buildings was nearly twice that of the land. The accounts do not show a separation between the amounts paid for buildings and land, but if these amounts could be obtained, they would show that the sums paid on account of the land, in excess of the appraised value, would be a large part of the $485 000 excess, for the reason that it is difficult to sustain a claim for the value of a building much in excess of its value for general purposes.

The 69% previously stated is, therefore, probably much more than the excess cost of the buildings, and much less than the excess cost of the land, over their values for general purposes. It is to be noted, also, that in the acquisition of this property most of the land was taken in whole tracts or parcels, so that there were no severance damages in connection with such portions of the property.

The accounts do not show the sums paid for strips of land taken for aqueducts or pipe lines in comparison with general land values, but the original estimate of the cost of these strips was obtained by multiplying the general value of the land by six, and adding a percentage for overhead charges. The actual cost corresponded very nearly to the estimate.

An illustration which is in marked contrast to the New York Catskill water supply is that of a railroad line in friendly territory, and is as follows:

LAND PURCHASES.

Details of Knife River Branch, N. Dak., Northern Pacific Railway.

	Mercer County, N. Dak.	Dunn County, N. Dak.
Valuation of naked land per acre, made by real estate men and bankers, not by employees	$22.07	$22.13
Total	$15 709.42	$12 065.12

	Mercer County, N. Dak.	Dunn County, N. Dak.
Total number of deeds	86	63
Total acres conveyed	784.97	615.55
Average acres per transfer	9.12	9.77
Total consideration	$24 460.	$17 106
Average consideration per acre	$35.00	27.80
Total number of considerations	4	None
Acres condemned	70.83	....
Award in condemnation cases	$1 966.52	....
Average per acre, award	$27.70	....

Summary, both Counties:

Total naked land value	$27 774.54	62.32%
All other elements of value	16 791.89	37.68%
Total purchase price	$44 566.43	100%
Expense of acquisition	$9 258.79	
Percentage expense of acquisition to purchase price	20.77	

Expense of Acquisition:

		Average per deed.	Average per acre.
Services and expenses, right of way agents	$6 790.75	$46.19	$4.85
Services and expenses of attorneys	705.69	4.80	0.50
Costs of abstracts and opinions of title	1 227.80	8.35	0.93
Cost of recording deeds	329.55	2.24	0.23
Automobile hire	205.00	1.40	0.15
	$9 258.79	$62.98	$6.66

This case affords an illustration of the extremely favorable cost of acquisition. The line was desired by the people. There was but little contest, as two of the condemnation cases were to acquire land owned by the State of North Dakota, the other two being against land companies. Every individual owner was settled with, yet, in spite of these facts, the land cost was $27 774.54, while "other elements" plus cost of acquiring was $26 050.68, or 93.8% of the bare land price.

The conclusion to be drawn from a study of all the figures available to the Committee is that costs of acquisition, like the element of damages in the consideration, are variable, that each valuation must stand by itself, and that, in fixing a figure for land reproduction, the appraiser must take into account all special local conditions. It is perfectly clear that no general average percentage which is universally applicable is to be derived from these figures.

Conclusions.—Cost of Reproducing Land Holdings.—Separate parcels of land, such as one or two lots, or a tract of not unusual size not connected with other lands by the utility in a strip or body, and where freedom of choice in selection may be exercised, should be valued on the same basis as other lands in the vicinity used for general purposes, plus a reasonable allowance for costs of acquisition and other proper overhead costs. The normal market value of parcels of like size, character, and availability, in the immediate vicinity should be accepted as a basis for reproduction cost determination.

Where large tracts have been acquired, made up of a number of separate entire parcels, the history of the transaction should be completely investigated and allowance made in the estimate for costs of acquisition and costs of vacation of streets or acquisition of other rights incident to the use of the property as a whole. Such further allowances should be made, as may seem to be justified by experience, to cover excess costs over and beyond the normal market values which existed at the beginning of the project and were due to fluctuations of price or other causes beyond control. Normal market values of similar and near-by property as of the time of appraisal should be the basis, with such additions as are warranted by the investigation in each case.

In the consideration of values of lands, such as rights of way for a railroad, an electric railroad, an aqueduct, or other like property, or, such as lands for a water-works or an hydro-electric reservoir, freedom of choice is restricted, and where all the land must be acquired, radically different methods must prevail.

In the valuation of lands of this class, a clear distinction should be made between:

(*a*) Lands where the entire tract or parcel is taken and there is no element of severance damages.

(*b*) Lands where only a portion of the tract is taken and where the element of severance damages is present,

and the extent of lands of both classes should be shown.

Historic conditions, where ascertainable, should be given due weight in fixing the extent and character of the severance. The estimate of reproduction should include a proper figure for such as was actually incurred, but should not include allowance to cover speculative or hypothetical damages on account of changed conditions. All elements of value to the seller, including recognition of all damages to the portions of his property not taken, which would prevail in the case of condemnation of the lands under reproduction, should be considered.

A determination of the relation existing between actual recent acquisition costs and the normal market value of the lands out of

which the strip or parcel was taken at the time of acquisition is undoubtedly possible in many cases. It would seem that where such relation can be determined, its use in connection with the normal market values of these or similar lands at the time of appraisal should establish a reasonable cost of reproduction.

There must be kept in mind the fact that no general rule can be established capable of universal application. Conditions that will apply in the acquisition of railroad lands in a large city, or in a fully developed rural community where lands are subdivided into relatively small tracts and with many improvements upon them, may not be at all applicable in districts where lands are held in large tracts with few improvements, such as grazing districts or a heavily timbered district.

The determination of the figure to be used must be based on full consideration of present normal values of general purpose lands, recent purchases by the same or other companies of similar lands in the vicinity or in districts of like characteristics, the extent to which damages enter into the cost of lands, and the amount and character of costs of acquisition and overhead charges. All elements of costs—normal market values of individual parcels, including improvements thereon, severance and consequential damages, enhanced prices induced by active demand, expenses of acquisition and overhead costs, and any other real items of cost which would be included in case of purchase—should be included in reproduction, but no allowance for special values coming after the acquisition of the property, on account of its new use or on account of a greater earning power under the new use, or any other hypothetical "value", should be included.

Estimates should be based on prices and values as of the time of appraisal, be they higher or lower than those prevailing at the time of original acquisition. The thing sought in reproduction is the fair cost of acquiring the property as of the date of valuation.

The treatment of the valuation of land holdings is not yet thoroughly crystallized, therefore the valuing engineer will do well to confer with counsel upon the interpretation of past Court decisions and the legal principles which are most fairly applicable to the case under review.

Overhead Charges.

General Nature of Overhead Charges.—There are certain expenses, inseparable from the construction of any property, which are a necessary and proper part of its cost, but which are not capable of physical identification after the completion of construction work. These expenses cannot be covered in the estimate of "Cost of Reproduction" by the application of specific unit prices; from their nature they attach to the whole or large parts of the property rather than to any particular units. These are called "Overhead Charges".

If the reproduction estimate is to be complete, and is to include allowances for all the labor that was performed, all services that were rendered, and all expenses that were incurred in the construction of the property under investigation, it is clear that a proper allowance, in some form, must be made for these expenditures.

Recognition of Overhead Charges by Courts and Commissions.— Overhead charges in one form or another have been allowed in all past valuations. Commissions have recognized their propriety, and Courts have endorsed their allowance.

One of the most recent cases involving the allowance was the Des Moines Gas Company case. A part of the decision (238 U. S., 153) is quoted as supporting the argument of the Committee that these allowances should be made in amount sufficient to cover all real elements of overhead costs, and no more.

"What is called in this summary 'the present value of physical property', the report shows was arrived at by the Master in the manner following:

"He first found what he thought was the base value of the property, *i. e.*, 'what it would cost to produce it at the present time new, without adding thereto any overhead charges'. This figure he fixed at \$1 975 026. To this he added overhead charges, 15 per cent., \$296 254. From this he deducted depreciation, \$333 878, leaving as the value of the property thus ascertained, \$1 937 402."

Mr. Justice Day further said:

"These items of expense in development are often called overhead charges, for which, as we have already seen, the Master allowed 15 per cent. upon the base value (exclusive of real estate), or \$296 254, in addition to his allowance of \$6 923 for organization expenses. Of these charges the Master said:

"'In reaching the physical value of the plant in question by the process of reproduction, it is necessary to bear in mind that the present value thereof represents much more than the machinery therein, the labor of installing and constructing them, and putting them in place to perform their various functions, ready for the manufacture and distribution of gas to its customers. Were the City of Des Moines without such a plant, and such a one as the Complainant now owns was proposed, it would be found that much more than the mere cost of labor and material would be expended. Such expenditures are termed overhead charges, and are as follows':

"'1. Time and money expended in the promotion of the enterprise, in the organization of the company and interesting capital therein, including, also, legal expenses, obtaining the necessary franchise, as well as the costs of incorporating the company.'

"'2. Then a competent engineer must be employed to prepare the plans and specifications for the plant, and make the necessary surveys, and when the work began, to superintend the construction thereof, and see that it is done properly and according to plans and specifica-

tions. The successful operation of the plant depends largely upon its proper construction.'

" '3. Then losses arising from accidents and injuries to workmen as well as the material during its construction, which is such an amount as the cost of insuring against such losses, which is between 1 and 2 per cent.'

" '4. Contingencies are such expenditures as arise from the lack of foresight and care in preparing the plans and specifications. No matter how carefully the engineer may prepare them, such expenditures invariably arise. Mr. Alvord testified that his allowance therefor would depend very much upon his knowledge of the engineer who prepared them, but that no matter who prepared them, they would invariably occur, and an allowance should be made therefor. The careful and thorough inventory in this case reduces very greatly the allowance therefor.'

" '5. The cost of administration, which includes the time and money expended by the parties who are engaged in the enterprise, purchasing the material, procuring the money for their payment as needed, and generally superintending the entire enterprise during the construction of the plant.'

" '6. It is estimated that it would take three years to complete the plant in question, and that at least one-half the time and money invested therein would give no return, and that a loss of interest would result therefrom and that such loss would be included in the overhead charges.'

" '7. Taxes during the construction.'

" 'The latter is regarded by me as very questionable. It is in a certain sense making taxes an asset rather than a liability, and the amount is so vague and uncertain that it has been given very little consideration and weight in fixing the overhead charges. Either the money or the property should pay taxes.'

" 'It must be borne in mind that these expenditures are all made during the promotion and construction of the plant, and are necessarily a part of the cost thereof. No overhead charges that do not inhere in and add to the cost thereof, should be allowed as a part of its physical value. It is not a question of what was actually expended therefor in the plant in question, but what would it cost to reproduce a similar plant at the present time.' "

In the actual construction of any property the expenses properly includible under "Overhead Charges" are actual physical costs of construction. They are in no sense intangible or non-physical values; they are not to be confused with development expense, as defined by the Committee, or going value; and must be set up as part of the physical property itself.

The late Judge R. W. Taylor, acting as arbitrator in the Cleveland Street Railway franchise hearing, said:

"Overhead charges as I have used that term and applied it to this situation means only those things for which money has been spent in the necessary work of constructing the property and putting it

into operation * * *. What I want to emphasize is that every dollar of overhead charge which is allowed for by me is a dollar that is necessarily spent in the production of the physical property."

What is true in this respect of an actual construction is also true of a reproduction estimate.

Expenses to be Provided for:

Among the expenditures which must be provided for, and classed as overhead charges are:

(*a*)—Cost of promotion;

(*b*)—Cost of financing and securing the necessary capital with which to carry out the enterprise;

(*c*)—Cost of organization, including the incorporation and organization of the company, securing of franchises, and other like expenditures;

(*d*)—Engineering, including the making of the preliminary investigations and plans, plans for the construction of the entire property, the engineering supervision of all construction and other work involved in the development of a property, except such direct supervision as may properly be included in the unit prices of various property units, or as specific charge against some particular schedule or group of units;

(*e*)—Administration, including salaries for general officers, agents, accountants, clerks, and other assistants, not included in the engineering and legal departments, and all administration expenses;

(*f*)—Legal, including salaries and expenses of law officials and costs of litigation which, depending on the character of the property and its location, may be a comparatively minor item or a very large one;

(*g*)—Interest during the period of construction on money borrowed, or on money invested in the property by its owners;

(*h*)—Taxes and insurance during construction;

(*i*)—Contingencies representing expenditures which cannot be foreseen but which from one cause or another are always of considerable size in the construction or reproduction cost estimate of any great enterprise.

These expenditures, and in some cases others of like character, are all involved in greater or less amounts in the construction of every property. They are represented by no physical property item which can be weighed or measured. They attach to the property as a whole.

Reasonable amounts can be determined for each property by a study of the history and accounting records of that property and

of other similar properties similarly located and built under like conditions.

It is a fundamental principle of valuation recognized by the Courts and commissions, and accepted by this Committee, that under normal circumstances the cost of recently created property furnishes the best basis for determining the reproduction cost of such property.

The Committee recognizes the value of the study of overhead expenses, incurred in connection with the construction of properties similar to the one under consideration, but it does not endorse the inclusion of any allowance which does not represent a legitimate expenditure of money or service in connection with the creation of the property under valuation, merely because such expenditures have been incurred for other properties. It does, however, endorse the inclusion of sufficient allowances to cover all legitimate expenditures, and it favors the use of the percentage on physical costs or any other method that will give fair and correct allowances.

See also the discussion under the caption "Shall Present or Original Physical Conditions Govern" (pp. 1761 to 1768).

Auxiliary or Collateral Costs.—Some engineers, particularly on the Pacific Slope, where large public works are more often executed by day labor than by contract, are in the habit of keeping their cost record data, and hence of estimating the cost of work, by including the so-called "Auxiliary" or "Collateral Costs", comprising incidental road or railroad construction and maintenance during the execution of the work, machinery and plant required, and various other similar classes of expenditures incident to the building of the works, in a percentage, applied to the basic material and labor costs involved in the various units or classes of work. Thus, for instance, though the labor, cement, sand, and gravel costs would be included by these engineers in the unit cost per yard for concrete, the cost,. rental, or maintenance of the machinery used in the mixing of the concrete, the cost of the construction and scrapping after the completion of the work of the bins, railroad tracks, towers or travelers of one kind or another, used in the mixing, delivery, and placing of the concrete, would be included in the percentage applied to the above stated unit costs to cover so-called "Auxiliary" or "Collateral Costs". In this report it is assumed that the auxiliary and collateral costs are included in the basic unit prices.

Character of the Items Classed as Overhead Charges.—It is deemed proper by the Committee to present the considerations which prevail in the allowance of various items of overhead charges, some examples of actual costs and allowances under each head, and some of the more authoritative decisions approving such allowances.

(*a*)—*The Cost of Promotion.*—The period prior to the commencement of actual construction of physical properties is, in the case of

most properties, divided into two parts: the period of promotion and the period of corporate organization after the promotion has been brought to a successful issue.

It is clear that the amount of money actually spent in promotion may have a wide range. In the case of such properties as hydro-electric power developments, years of time and large sums of money may be required to secure title to lands and flowages and to bring the project to such form as to justify the attempt to raise funds for actual construction. Other properties may involve but little expense or but little outlay or money. Still other properties may have a large or small outlay on the initial construction, but the major part of the property, developing after operation of the pioneer lines, and built as additions to an existing operating property, may have very little actual cost of promotion.

The argument supporting the allowance of cost of promotion is ably stated in the decision of the Michigan Railroad Commission in the hearing on the application of the Northern Michigan Power Company for authority to issue securities. The decision, written by Commissioner Lawton T. Hemans, discusses "Cost of Promotion", in connection with the cost of acquisition of lands for hydraulic purposes, as follows (19 A. T. and T. Co. Com. L-253-254, June 11th, 1913):

"Another item which it seems to the Commission is properly included in the value of lands for hydraulic purposes, under the Commission's general designation of 'reasonable compensation for the time, energy and ability bestowed in their acquisition', is the item quite generally denominated 'promoter's profit', but which this Commission believes would be more truly descriptive if denominated 'cost of promotion'. The man who devotes his genius to enlisting support for great enterprises of public benefit, which his clearer foresight and keener vision has first perceived in the great world of material development, has performed services quite as valuable to the public as the engineer who later makes computations, plans and specifications, or the man who in any other position contributes to the creation of the utility.

"In passing upon the value of services of this character, the New York Public Service Commission has said that such services 'should be fairly and even liberally rewarded by the public which receives the benefit of these works. Such rewards, however, should be put upon a clear basis of business principles, should be of sufficient magnitude to encourage rather than discourage enterprise, and should not be so great as to make an exorbitant demand which is perpetual in its nature upon the community to be served. They are to be treated simply as just payments for services performed for the corporation, which services are valuable and in many cases even indispensable. Such services should be paid for upon the basis of what they are fairly worth, having regard to all the circumstances of the case'. (*In re* application, Rochester, Corning, Elmira Traction Co., 1 P. S. C., 2d D., N. Y., 166.)

"In the above case the award was made upon the basis of five per cent. on the entire cost of the enterprise, which had a total cost approximating seven million dollars. Other awards have been made by the New York Commission of varying percentages upon the estimated cost of the particular utility.

"In the matter under consideration, request is made to include in capitalization as compensation for promotion, two and one-half per cent. on the estimated cost. The Commission is persuaded that in cases of this character the item of cost of promotion attaches peculiarly to the lands and flowage rights of the development, for, if it is to be justified, as we have indicated our belief it should be, as compensation for a peculiar service incident to every comprehensive scheme of material development, then it should in principle inure to the value of the thing in relation to which the particular service was rendered. It should be compensation to the pioneer, rather than to those who claim neither originality of conception or to have assumed any of the risks of development."

That this element of cost is recognized by the Interstate Commerce Commission is shown by the provision, in the account designated as "Organization Expenses" for

"* * * Cost of preparing and distributing prospectuses; cost of soliciting subscriptions for stock; cash fees paid to promoters, and the actual cash value (at the time of the organization) of securities paid to promoters for their service in organizing the enterprise."

Examples of actual costs of promotion are difficult to cite, for the reason that the accounting for such costs has been as a rule under the head of general expense, or of organization, and have been merged with other costs which belong properly in organization, administration, or legal expenses.

(*b*)—*The Cost of Financing.*—When the project of the promoter has been investigated and found to be sound, and after a plan for the financing of the company has been adopted, there is incurred considerable expense in connection with the issue and sale of stocks or the issuing and marketing of bonds and the payment of commissions to brokers. There can be no question as to the necessity for such expenditures. They are unavoidable, and should be allowed in proper amount.

Whether discount on securities is an allowable item, is an open question. Discount may be a partial capitalization of the commercial risk had in making the investment, it may be an indication of lack of credit on the part of the company, or it may indicate that the interest rate on the bonds is lower than the conditions of the market would warrant, and the discount is in effect an adjustment of the interest rate or a prepayment of interest. If the company secures the benefit of the low interest rate, it would be unfair to capitalize the discount. Nor would it seem any more fair to capitalize excessive risk or poor credit.

That regulating authorities and Courts are not in perfect accord, is shown by the conflicting opinions quoted.

In a Montana rate case (198 Fed., 1003), Judge Hunt says:

"The master allowed 15 per cent. of \$562 715.89, or \$84 407.38, as a necessary and usual item of cost of reproduction. There was no evidence offered on behalf of the Railroad Commission tending to dispute the conditions which the witnesses for the complainant said existed generally throughout investing communities, namely, that a railroad, such as the one under investigation, is only able to make its financial arrangements by regarding as a part of the construction cost to which it is subjected a discount representing the difference between the amount derived from the sale of its bonds and the amount which the bonds must eventually cost the company. Recognition of discounts on securities, based upon the considerations just expressed, has been made by the courts. Of course there never could be any allowance whereby a corporation can be allowed to capitalize its own lack of credit; but where the bonds are sold at a reasonable discount, and bear a low rate of interest, it would seem to be the equivalent of selling the bonds at par with a high rate of interest. Here the 15 per cent. seems to be reasonable, the testimony showing that upon such a discount the bonds are put upon an equality in marketable conditions with the bonds of some of the very largest and most successful railroads in the country."

Commissioner Hemans, in the Northern Michigan Power Company case, says:

"The application filed herein makes request for the allowance of an item of 2½ per cent. on the cash cost of construction and physical properties to cover the item of banking and brokerage. Unquestionably every comprehensive development of the character being considered finds it expedient to enlist the services of a reputable broker who must be compensated for the investigation he shall make into the basis of the securities, which, if found satisfactory and desirable, he shall recommend to his clientage, but it is a service that is incidental to the sale of the securities or the borrowing of capital. It is an item most intimately connected with bank discount which is in part the rate which a given concern must pay for its loans. We believe that under prevailing practices, in view of the discount at which it is desired that the bonds to be authorized herein may be sold and at which like securities are sold, there is no justification for the inclusion of this item in capitalization, but that it should be included with the bond discount and ultimately extinguished by amortization from the profits of operation."

In the Des Moines gas case (238 U. S., 153), already quoted, Mr. Justice Day quotes the Master, as follows:

"Time and money expended in the promotion of the enterprise in the organization of the company and interesting capital therein, including also legal expenses, obtaining the necessary franchise as well as the costs of incorporating the company."

The Committee is of the opinion that the cost of financing should include all fair costs for interesting capital and issuing and marketing securities. Discount on securities should not be included in capital, but should be amortized over the period of the life of the securities. The fair cost of financing will depend on the probable rate of return, the credit of the promoters, and the degree of hazard attending the project. If a sufficiently high rate of return is assured and the credit of the promoters is good, the cost of financing should be low, little more than an ordinary brokerage rate. Poor credit should not be considered in estimating cost of reproduction, but probable rate of return and the hazard of the enterprise should be considered, and the fair cost of financing estimated as affected thereby.

(*c*)—*The Cost of Organization.*—Under this caption is included a class of expenditures common to all properties, distinct from "Cost of Promotion" in that they usually follow the promotion, and are incurred after the project is assured. There may be many cases in which they merge with the cost of promotion. There are undoubtedly some cases where "Cost of Promotion", "Cost of Financing", and "Cost of Organization" may all be includible under the head of organization. The class of expenses specifically referred to includes costs connected with incorporation and securing a charter, cost of securing franchise, local grants, consents of property owners, consents of the Government, as in case of construction over or under navigable waterways, and all other expenses connected with the organization of the company which is to build the property, and the securing of all the necessary rights, grants, and privileges necessary to permit it to proceed with actual construction.

In Bonbright *vs.* Geary (210 Fed., 44), already quoted, there were included "The legal expenses of organization."

In the Des Moines gas case (236 U. S., 153) there were included "legal expenses obtaining the necessary franchise, as well as the costs of incorporating the company."

In the Knoxville case (212 U. S., 1) the sum of $10 000 was allowed for "Organization, Promotion, etc." The Court assumed this to be a proper allowance without deciding.

(*d*)—*Engineering.*—As an "Overhead Charge" there should be included all engineering costs not capable of specific assignment to property units or special parts of the property.

The general engineering charge, in the case of most properties, is a very considerable item, in some cases amounting to a large percentage. The percentage differs with the character of the works and with the care and skill exercised in their construction.

In the case of a railroad property, general engineering includible as an "Overhead Charge" would cover all the reconnaissance or general investigation of the territory through which the line was to run,

the preliminary surveys, the final location, the general supervision of the chief engineer and assistants whose time is devoted to general, not specific, work, all services of consulting engineers not capable of definite assignment to specific units of property, and much of the expense of the office staff of the chief engineer's office.

In the case of most old properties, it is difficult to draw exact lines between these general engineering expenses and the engineering and inspection during construction, and in many instances it may be desirable to include all engineering as an overhead charge.

In connection with a water-works property, large expenditures must be made for investigations of drainage areas, general surveys, plans and specifications, and general supervision of all construction.

In the illustrations cited of actual engineering costs, no attempt has been made to segregate general engineering charges and direct supervision, all preliminary, general and direct charges being lumped. In case the segregation can be made, it will be found in every case that the overhead charge for general engineering is a very considerable item, which cannot be overlooked or dismissed because of charges to direct supervision.

Examples of actual costs of engineering indicate that there is a rather wide range in the percentage, even on the same kinds of property, due to the presence or absence of a large number of property units which carry high costs of direct supervision. This goes far toward supporting the argument of the Committee that these figures should be analyzed.

The construction of an important dam or aqueduct, built in place and requiring skill in designing, and a careful inspection of every part of the work as it is built, requires a larger expenditure for engineering than a large cast-iron pipe line, where the cost of laying the pipes in a trench is but a small percentage of the total cost of the line, and the work progresses so rapidly that the inspection cost is small in proportion to the total cost. The charge to direct supervision would be much greater in one case than in the other, and if such charge be made, general engineering overhead charge will be more nearly comparable with other like properties.

The cost of engineering varies, not only with the class of work, but with the character of the design and method of its execution—whether by day labor or contract, and in the latter case the nature of the contract. Works may be built with little inspection, from crude designs prepared by unskillful engineers, with the result that the cost of works may be large, although the percentage paid for engineering may be small. Works skillfully designed and efficiently constructed imply a larger cost for engineering, which should be recognized in any valuation when the works give evidence of such skill and efficiency.

(e)—*Administration.*—Under this head should be included all allowances to cover the salaries and expenses of executive officers during the period of construction. Also all clerks and other employees, office rent, and expenses in connection with the supervising, accounting, and other offices, except law or engineering.

This allowance should cover, when necessary, all general police and sanitary department employees.

These expenses, like those for engineering, vary, depending on the character and location of the work, legal requirements, and methods of construction followed.

As accounting records have been kept in the past, they are difficult of exact analysis by examination of old records of construction, as they have often been merged with other accounts. There has been such a universal recognition of the propriety of the inclusion of an allowance in proper amount that no argument is considered necessary.

(f)—*Legal Expense.*—The law expense incident to construction will vary greatly, depending on the character of the work, the population in the territory in which the work is being done, and the laws which control the operations of corporations as to securing rights or as to construction.

One property may be situated so that few if any obstructions are placed in the way of its construction, and another similar property, in another State, may have not only to pay large sums for legal services necessary to carry out the requirements of statutes and ordinances, but may have to resort to extended litigation before the work is completed. This fact makes necessary a consideration of the history of the property in connection with the allowance for "Legal Expense". This allowance has been made in nearly all past valuations. It is a proper allowance, and should be made in such amount as will adequately cover the expense in each case.

(g)—*Interest During Construction.*—Before the construction of works of magnitude can be undertaken, financial arrangements must be made for the advance of the necessary funds. If the period of construction involved be comparatively short, such as one or two years, it has generally been found advantageous, if not necessary, to borrow the entire sum needed in advance of construction. If, on the other hand, the period of construction is a long one, such as from 5 to 10 years, as is true in the case of most large properties, or large parts of properties which have been built during one construction period, instead of developing from small beginnings, it is generally found advantageous to make arrangements for the advance of stated sums at different times during the construction period. Generally, bankers and underwriting syndicates prefer, however, to make arrangements on the basis of purchase of the entire bond issue, though the bonds be delivered at stated intervals in blocks, and allowance be

made for repayment of a nominal rate of interest, such as 2% on unexpended bank balances.

Necessary financial arrangements involve the payment during the construction period of interest on the funds borrowed, or advanced by the owner of the property. It is logical to include these interest payments in the construction cost of the property up to the time when the workable units of the plant are put into actual revenue-producing operation; then the interest payments involved by the investment in the unit of operating property should be accounted in development-expense during the period involved in the acquisition or establishment of the business to the point where the earnings are sufficient to meet the fixed charges, as well as the operating expenses and depreciation allowance; thereafter, the interest payments should be accounted as fixed charges, to be met from the net revenue or divisible earnings of the property.

The determination of the exact time when the different workable units of the property may fairly be assumed to have crossed the dividing line between the "construction-period" and the "physical development-period" is difficult; but this is not a matter of controlling importance if proper allowance be made for the development expense element of the value in the property.

All the arguments for the inclusion of a proper allowance for "Interest" are stated so fully by the Wisconsin Railroad Commission in the Madison Gas and Electric Company case (4 Wis. R. C. R., 501-541, decided March 8th, 1910), that no further discussion appears to be necessary:

"While all these points are interesting, and contribute to an intelligent discussion and determination of the question at issue, it would seem that the interest during construction, correctly allowable in a valuation under ordinary conditions, would be interest at the current rate on the cost of each part of the plant during its construction. The element of cost by reason of interest during construction is one which cannot be escaped. It is present to some extent no matter what the method of financing the construction may be. From the time the investment for construction is made until the completion of the entire plant enables the investment to become active as an integral part of a working whole, there is the element of interest, for that investment is necessarily involved and is necessarily idle until the completion of the plant to a working point. The fact of interest, like the fact of depreciation, is present, no matter what method is employed for financing it. This is as true when the money is furnished by the owners as when it is borrowed by them. The theory upon which such interest rests is sound, and remains so even in isolated cases where the investors decide to charge no interest, and choose to donate the same to the consumers in the way of lower charges for the services rendered. Even if the company let a contract for the complete construction of a plant, to be paid for in no part until wholly

completed to the operating point, interest cost would come in as a part of the contract price, even though not expressly set forth. In that case the contractor would have to ask a higher price to cover the interest cost. Some additional compensation is needed for the investment made by him during the progress of the work and which is necessarily idle until the completion of the plant. Should the company itself construct the plant and be able to arrange to do the entire work on credit—gathering the material, machines and equipment, labor and everything additional needed on credit, to be paid for at the completion of the plant, at the point of operation—the interest cost would nevertheless enter in some form in the entire cost of construction."

It has been the practice on many valuations to assume a period of construction, and to assume that the interest during the period of construction would equal the interest for the entire period on one-half the total cost. In making the assumption as to a proper period of time in which any property could be constructed in connection with the reproduction estimate, due consideration should be given to the actual history of the development of the property, and to the sequence in which the various parts of the property were built or would be built under present-day methods, and making use of existing facilities. Allowances for interest and other overhead charges should be based on actual experience in the construction of the property under investigation, or similar new properties, as far as possible, and not on any such general assumption as stated, as such assumption is likely to give results which would be too small in many instances and excessive in others, and the attempt should be to determine a figure which will be just and equitable in each case.

Some of the earlier railroad appraisals assumed that the property would be produced in short sections, each taking one year for construction, and that an allowance of 3% on the entire cost, or an average of one-half year's interest, would be ample.

While it is undoubtedly true that some properties have been built and opened to traffic in short sections, and have thus carried a small interest charge, and some of these properties would be so built if they were to be reproduced, such an assumption is not applicable to all properties.

From the viewpoint of reproduction under present conditions, interest during construction should be based on carefully prepared construction and financial programmes which will provide for a proper period for reproduction, giving due regard to the history of the enterprise and to the periods of times required for the construction of different portions of the property, as well as a reasonable sequence in the order of reproduction, and will provide fully for all economies. The financial programme should be so adequate as to provide ample funds and materials, as needed during construction, and to eliminate

delays. The rate of interest should be based, not on the financial credit of the property at the time of appraisal, but on the assumption that the property is a new property, and will be developed during the reproduction period assumed, and giving due weight to the hazards attached to each property.

From a strictly historic point of view, the time for which interest during construction should be allowed should be determined on the basis of historic conditions, in the same way as other items entering into the estimate of cost, except that normal present conditions should be used in fixing the rate or rates of interest to be used. Due regard should be given the history of the property as to its effect upon the credit of the company, having in mind that in some existing utilities large parts have been built piecemeal after the original property had been fully established, without the degree of risk and hazard attending the building of the original property, and that in some other utilities the risks attending the development of the additions were fully as great as those attending the construction of the original property. The financial programme should be so adequate as to provide such ample funds and materials as would be needed during the construction periods of the different parts of the property to eliminate delays.

It is not intended by the above statement to suggest that it is necessary to obtain the history of each item added to the original property or used to replace an item which has reached the end of its life, because this would be impracticable and unnecessary; but that the historical basis should be used as a guiding factor in determining the period for which the interest during construction of such items or classes of items should be computed. In other words, the interest during construction allowance for items added to a property from time to time after the original construction should extend only over the period of time required to build each particular item and put it in operation, with a reasonable addition to provide for procuring the money in advance of the beginning of construction.

Interest should then be computed on the various parts of the property, taking into account the time required to construct each and the total time that must elapse from the completion of that part until the operating units of property reach the point of revenue-producing operation.

(*h*)—*Taxes.*—The money paid out for taxes on lands, buildings, materials, and equipment during the period of construction of a utility property would seem to be so obviously a proper charge to capital invested in plant as to require no supporting argument, yet it has not received the unqualified endorsement of the Courts. An illustration may be cited in the case of an electric light and power company in a large mid-western city. The rapid growth of the city and increase of the business necessitated very large increase in the plant facilities, and

it was determined to build a new power station in a new location. A tract of 22 acres was acquired in 1911, and work was at once commenced on preparation of plans. Actual construction was begun in the spring of 1912, and the plant was put in operation during the summer of 1915. During this period 3 full years taxes on the land were paid, and the increase each year in the assessments, on account of the improvements, resulted in a payment during the period of more than four times the tax that would have been paid on the basis of the assessed valuation at the time of purchase. This expense is unavoidable; it is, like interest, a charge that must be provided for, and met out of funds raised for construction. The percentage of the total construction cost may vary on different kinds of property, and care must be taken to make sufficiently full investigations to insure the accuracy of the estimate. The Committee believes that an allowance for taxes, in proper amount, is a fair charge to construction, and should always be included in the reproduction estimate.

(*i*)—*Contingencies.*—Contingencies in construction are those added costs or added items of construction which are made necessary by unforeseen difficulties, or events beyond the control of the builders, or are due to conditions which were not fully determined at the inception of the work. Similarly, the contingencies in an estimate of reproduction are those due to conditions which could not be fully determined at the time of making such estimate of cost and such conditions always prevail, in greater or less degree, depending upon the character of the property and local conditions, the age of the property, the available records, and many other factors.

Contingencies vary in amount with different kinds of property and with different property units. On classes of work in which the contingency item is likely to be large, the proper percentage to allow for contingencies will depend largely on the extent and accuracy of the investigation.

Perhaps no one item of overhead charges on past appraisals has drawn more criticism, and in some instances ridicule, than the allowance for contingencies. The Committee, at the outset of its discussion of the subject, desires to state that no allowance for contingencies is advocated that is not a reasonable one.

It must be emphasized that the allowance for contingencies is an allowance for the unseen and indeterminate cost in reproduction which could not be seen, investigated, and determined in advance of original construction, or at the date of valuation. Many people appear to be unable to realize the fact that it is not possible to see all the things that were done and know all the conditions that accompanied the doing of them when investigating an existing great public utility.

It is fully as difficult to estimate correctly the cost of reproducing an existing property as it is to estimate the cost of producing one

which does not exist, and it may be more difficult. To illustrate, assume one of the large hydro-electric developments or water-works reservoirs. The property is, let us say, 12 or 15 years old. The valuation engineer finds a massive masonry dam, some buildings and equipment capable of definite measurements, and a large lake or water covering several hundred acres. All roads, railroads, and other property surrounding the reservoir are in good condition, and their appearance would not indicate whether they were 12 or 40 years old. The plans, field notebooks, and construction records may be complete, but are more likely not to have been fully preserved, as in many properties the value of old notes and construction records has not been recognized. The problem is to estimate the cost of reproducing the property. There will be many costs which can be covered only by a contingency allowance.

The construction engineer, about to enter upon the construction of such a property, finds in the valley to be occupied all the various properties and constructions that are to be removed, he has available the results of explorations, surveys, soundings, borings, and other investigations which will determine what will be encountered. He has equal knowledge with the valuation engineer as to costs of material, labor, transportation, tools and equipment, and other things needed, and his facilities for accurate estimating are just as good. Yet, in producing the property, he encounters costs not foreseen, due to weather, floods, labor troubles, transportation difficulties, delays, and many other causes.

The contingencies cannot be listed in advance—otherwise they would not be contingencies.

Those who ridicule or omit contingent allowances, or argue that they apply to individual items rather than to the plant costs as a whole, ignore general construction experience. The allowance for contingencies is not an allowance to cover error, as has often been assumed. To some extent contingencies in both construction and reproduction are due to failure to schedule completely all work to be done, but, to a far greater extent, contingencies are due to those unseen, unavoidable, and uncontrollable causes that neither engineer, nor owner, nor contractor can foresee.

Errors of judgment may occasionally add to the cost of construction, and the Committee is of the opinion that a provision for this is justifiable.

The Committee endorses no allowance for contingencies which will add arbitrarily a percentage to a thing that is known and definite; but it does contend for an allowance in all cases except those in which it is certainly known that contingencies would not be incurred.

Character of Contingency Expenses.—Omissions from Schedule.—In both construction and reproduction estimates on large properties, where many thousands of items of property are scattered over a wide area,

or, as in the case of railroads, over hundreds of miles of territory, there are certain to be omissions, not only of minor items, but of large items of property. This applies, not only to property which is capable of easy identification, but to a greater extent to that which was built in connection with the construction, and was essential to it, but which is not in constant use, and of which ownership consequently is finally lost sight of.

Hidden Construction.—Unless the most complete records are available, much of the expense which adds to the cost of foundations of all kinds is apt to be overlooked. Pumping or coffer-dams in some localities, and quicksand or other treacherous material often increasing the size or depth of foundations, makes the cost not only greater per unit but adds largely to actual quantities in excess of the plans. Costs incident to settlement of the surface on marshes, causing a large increase in the fill required, are sometimes included in contingencies, but should be allowed for preferably in the schedule of quantities.

Losses Due to Flood, Storm, or Bad Weather.—Frequent and unavoidable expenses are those due to storms, floods, slides, and wash-outs. There is also the added expense due to freezing or wet weather. The examples of this class are very numerous; hardly any large property has been built which has not had to contend with such difficulties.

Strikes, Labor Troubles, Delays in Delivery of Materials.—Labor troubles are a frequent and expensive occurrence, and, at times, not only delay completion, but add materially to the cost. The non-delivery of material, often necessitating the purchase of small quantities at high prices, or causing expensive delays, is another class of contingency expense which is continually met. Delays are often caused by injunction, or other legal processes or failure to raise the necessary funds as needed, causing, not only extra expense on the work, but loss of interest. The failure of contractors or the abandonment of work by them, is often a serious cause of contingent expense.

Moreover, it often happens on large works that the losses due to interruption of or delay in construction are largely augmented by the loss in efficiency of the working force, incident to building up a partly new organization upon the continuation of construction. The suspension of active work upon the construction of the Los Angeles aqueduct, due to temporary lack of funds, is stated in the report to have caused an additional expense of $250 000.

Construction Outside of the Main Property.—In nearly all large properties it will be found that, either owing to the special location or conditions, or on account of relations with the public or other owners, it is frequently necessary to build considerable work which is in no wise a part of the property under investigation, but is required to readjust existing conditions to permit the work to proceed.

Illustrative Examples of Actual Contingencies.—In building an electric road near Toledo, Ohio, contracts for grading were let at 22 cents per cu. yd. for earth. One section involved a crossing under a railroad. The presence of quicksand and water in the cut made ordinary methods of handling material ineffective, and the contractor failed. The work was completed on the basis of cost plus a percentage, at a cost of 84 cents per cu. yd.

In 1895 the Ann Arbor Railroad was raising an embankment over a swamp. A "sink hole" developed which broke under a freight train, causing not only a loss of many thousands of yards of earth, but damages to property of more than $25 000.

In March, 1905, the flood conditions in Ohio and Indiana were unusually severe. An electric railway bridge over the Maumee River was under construction, and seven high concrete piers were completed ready for superstructure. An ice gorge formed about 2 miles above the bridge, and when it broke two piers were swept away, involving a contingency expense of more than 15% of the entire cost of the bridge.

The Cleveland Railway, in the construction of a new car-house, lost the entire structure in a tornado after more than 70% of the work had been completed.

Elliot Holbrook, M. Am. Soc. C. E., cites examples of contingencies, as follows:

"A piece of construction with which the writer was concerned consumed over two years in construction, while it was expected it would be completed in one season. The result was that owing to increased outlay and greater length of construction period, interest alone was increased by an amount equal to 5 per cent. of the original estimate of total construction cost. A steel bridge near Anoka, estimated to cost $21 000, actually cost $32 000, on account of floods taking the coffer-dam out. Pipe line at Dassel, Minn., estimated to cost $6 600, actually cost $8 300, owing to delays that carried the work into winter, necessitating excavation in frozen ground. Bank widenings in Dakota, estimated to cost $15 000, actually cost $27 000, owing to excessive rains. Change of line from Teton, Mont., to Tunis, Mont., estimated to cost $10 500, actually cost $33 000, on account of a hill giving way and burying a steam shovel. A change of grade, estimated to cost $7 100, actually cost $12 000, owing to slides and wet conditions of material. New yard at Blair, Mont., estimated to cost $41 500, cost $66 700, owing to heavy storms washing out grading and causing delay. Drainage tunnel at Alvin, estimated to cost $16 700, actually cost $23 000, on account of trouble encountered with water. In fact, in the construction of a railroad, there is almost a continuous succession of unforeseen and unforeseeable difficulties that increase the time necessary for construction and the total outlay required."

In the case of subway construction now under way in the City of New York the provision originally made for contingencies, 5%,

has been found to be inadequate, and additional elements of cost have so far developed to indicate that they will amount to upward of 14%, exclusive of the provision that may have to be made for contractor's claims, and further charges for interest on money during construction caused by the non-synchronizing of completed portions of the system.

Many other examples have been cited to the Committee. It is believed that, if it were possible to separate from the bare cost of nearly all large works those items that were actually contingencies, the list might be greatly lengthened. Attention should be directed specially to the fact that nearly all available cost records give total actual construction, but do not give original estimates or originally estimated quantities. To determine contingencies therefor, it is necessary to go in most cases to the original records and make special analyses. This will account for the comparatively small number of cases in which this item of overhead charges has actually been segregated.

The close estimation of cost is an art, of which comparatively few men are masters. In its final analysis it is a matter of judgment, founded upon knowledge and breadth of experience in engineering construction, and discrimination in the determination of the relative effect of different conditions and factors entering into the problem, as well as in the application of well kept records of previously built works. Synthetic cost analysis has some advantages, if limited to the main and readily determinable cost influencing items, though it has the grave danger of implying a degree of accuracy in the results obtained, not actually realized, and the tendency to minimize and under-estimate the elements of hazard and uncertainty, which always exist to a greater or less degree, on any large construction work. Direct comparison with costs of other works, of similar character, under similar conditions, when possible, furnishes the most reliable guide. The method of always comparing the cost of different classes of work, on broad lines, with a previously determined "average-scale", based on general experience under more or less similar conditions, and getting the coefficient or factor, as compared with the average-scale, of each work, is most helpful, particularly to the young engineer.

Allen Hazen, M. Am. Soc. C. E., has discussed this subject in an admirable article on "The Art of Making Rapid and Reliable Preliminary Estimates of Cost",* from which the following paragraphs have been abstracted.

Extra Cost of Novel Designs.—Work on novel designs commonly costs more than work following standard designs. This is true even when well tried methods are first introduced in new places. Such work may be too small to attract bidders from a distance. The unit cost will then overrun anticipated prices. An under-estimate of cost is

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frequently made on work because the estimator fails to realize what a great effect familiarity with the methods of performing work has upon the cost. To realize this one has but to think of the difference between present methods and costs of building tunnels and subways and deep foundations, and the methods and costs of only 10 or 20 years ago. Not only is the risk which the contractor takes now less, but methods which have been thoroughly tried out are at his disposal as well as experienced foremen and laborers, to do the work more economically. For a structure of new or novel design much caution in using prices that may be standard on other kinds of work must be used.

Small Jobs Cost more in Proportion than Large Ones.—Another common cause of under-estimating costs is the use of figures on large pieces of work for estimating small work. The engineer often overlooks the large cost of overhead charges, the waste of labor and the cost of plant caused by organizing a force to perform a small piece of work. He too often forgets that for small work the work must be done by less efficient methods, or the cost of plant prohibits the use of expensive machines. Perhaps the most common case of such underestimating is where the job, although a large one in the aggregate, consists of many small pieces of work of widely varied character. Such a job is troublesome and costly for the contractor, and the experienced man knows it and puts in a corresponding bid.

It must be remembered that bids follow the law of supply and demand; that general slackness in construction work calls out bidders and low prices. The condition of the money market, the cost of materials, and the general opinion of the condition of contract work are of course matters of much importance. It seems scarcely necessary to say that the engineer should know where and how the contractor is to obtain his materials and have a fairly definite idea of the cost, either in dollars and cents or as a comparative figure to other work.

The engineer in estimating should try to look at the work from the standpoint of the contractor, should try to remember that no work runs as smoothly along as the contractor wishes, that labor conditions and other matters often spoil the best laid plans. He should endeavor to keep in mind the various work he has watched or performed and the numerous times when unexpected conditions added largely to the cost.

Generally speaking, estimates on proposed work by men of limited experience are too low, yet it is not unusual for an engineer to be so impressed with the difficulty of a piece of work that he over-estimates the actual cost, and it is more common to find that he has over-estimated the bids of the contractors.

It is of much value to have two methods of arriving at estimates. If an independent check method can be made, even though a rough

one, a failure of the two results to agree often leads to the discovery of serious errors in the application of one or the other method.

Conditions of Success in Estimating.—One of the first requisites for successful estimating is a fair and unprejudiced, and moderately pessimistic mind. The estimator must be alert for new and cheaper processes and methods. and conservatively sceptical concerning their merits. Moreover a successful estimator must have had experience in actual construction. As a general rule an engineer should not make an estimate for a structure that he would not know how to build.

Next, as a requisite to successful estimating, may be mentioned a broad basis of cost records of actual work, more or less similar to that for which estimates are to be made. A good and safe method of using the cost data and adjusting it for application to new conditions is equally important.

And, finally, the estimator must have the will to refuse to make estimates for work that he does not understand.

CHAPTER VI.

DEPRECIATION AND APPRECIATION.

Depreciation in Valuation.—Perhaps there is no single subject in connection with valuation that has caused more trouble than depreciation. This has been due to various causes, perhaps not the least of which has been confusion in the use of the term. Depreciation is sometimes used to mean decretion, which is loss of service life, sometimes to mean the money allowance made in the bookkeeping to offset accruing loss of service life, and sometimes the loss of value existing at any time due to the loss of service life or any other cause. The Committee will use it only as meaning the loss of value or worth of property units which are parts of going concerns. Although this may be due to many causes, the general discussion will include consideration only of those effects which, like wear and tear, age, use, and obsolescence, or inadequacy, bring a physical property unit gradually to the end of its service life.

Another difficulty has been the failure of owners and Courts to comprehend depreciation. Neither of these have realized in the past the necessity for and equity of earning and setting aside allowances to provide for accruing loss of capital due to the accruing, but not yet total, loss of service life of the parts of a property. Nor is this difficulty wholly removed at the present time. In the earliest decisions of the United States Courts bearing on this subject (Union Pacific R. R. Co. *v.* United States, 99 U. S., 402, and United States *v.* Kansas Pacific Ry. Co., 99 U. S., 455, both decided October, 1878), it was held: in the first case, that all expenses for maintenance of the property should be included in operating expense, only cost of original construction and subsequent enlargement and improvement of the works being capital expenditures; and it was even held that ordinary betterments wisely might be made from earnings, apparently without a charge to capital, a practice now generally disapproved by Courts and commissions; and in the second case, that no allowance for depreciation that does not represent cash actually spent can be included in operating expense.

Nineteen years later the Supreme Court of California (in San Diego Water Co. *v.* San Diego, 118 Cal., 556, 1897), mentions depreciation, and in the prevailing opinion given by Justice Van Fleet, reinforced by the concurring opinion of Justice Garouette, distinctly holds that an allowance should not be collected from the rate-payers for it, the concurring opinion saying:

"But such a thing is all wrong, for it results in the consumers of water buying the plant and paying for it in installments."

But it is fair to say that this concurring opinion is based on the notion that such things as tunnels, wells, reservoirs, water rights, and real estate suffer no depreciation;

"* * * there is no wear and tear, no permanent and gradual destruction by use and age. Most of them stand everlasting as the hills."

and that it further admits that the replacement of worn out items is a proper charge to operating expenses, saying:

"If improvements are made in the plant as it stands, as, for example, a new pipe substituted for an old piece of the same size and quality, such charge should be considered operating expenses."

which seems clearly to uphold what will be described later as the replacement method of maintaining property that is supposed to wear out. The decision makes the mistake of finding that certain items of property which do go out of service for one reason or another are "everlasting as the hills."

It is interesting to note that there was a dissenting opinion, handed down by Chief Justice Beatty, which says that after including as current expenses all operating expenses reasonably and properly incurred, taxes, and the cost of current repairs, there should be added to the sum to be collected annually an allowance for a sinking fund sufficient to replace any parts of the plant which, at the end of a term of years, will be so worn out as to require restoration, when this restoration occurs.

The foregoing is introduced because of the appearance, apparently for the first time, of a discussion of the propriety of collecting and setting aside a depreciation allowance, and particularly the approval of such a course as given in the dissenting opinion. A year later, the same Court (in Redlands, etc., Water Co. *v.* Redlands, 212 Cal., 312, 1898) said:

"In a municipal ordinance fixing rates * * * the water company is not entitled to be reimbursed from the income derived from rates, fixed by the ordinance, for interest upon its indebtedness, nor for depreciation of its plant, aside from the amount requisite for its maintenance and repairs during the year."

This decision was consistent with that in the San Diego case, and referred to it, and is here quoted because the United States Supreme Court (in San Diego Land and Town Co. *v.* Jasper, 189 U. S., 439, 1903) referred to this case with approval. And this was as late as 1903. The language used at page 446 of the report is as follows:

"We will say a word about the opposite contention of the appellant that there should have been an allowance for depreciation over and above an allowance for repairs. From a constitutional point of view we see no sufficient evidence that the allowance of six per cent. on the value set by the supervisors, in addition to what was allowed for

repairs, is confiscatory. On the other hand, if the claim is made under the statute, although that would be no ground for bringing the case to this court, it has been decided by the Supreme Court of California that the statute warrants no such claim."

Four years later, at least one Court had seen a light, for (in Perkins *v.* Northern Pacific Ry., 155 Fed., 445, 1907) Judge Lochran, of the Circuit Court of Minnesota, states, among other things:

"It is evident * * * that a railroad, like everything else, will wear out in time, and they have been used so long in this country that there can be a reasonable estimate of the percentage of loss each year from depreciation of the roadbed, culverts, bridges, and rolling stock; that it would be proper to lay aside a reasonable amount to furnish replacements, renewals, and repairs when needed; and that if that was not done the railroad company might soon be in a position in which it could not keep up, with the rates that it was getting, and maintain its property in an efficient state to render such service as the public is entitled to receive from it. Now this is a matter in which the public has an interest as well as the railroad companies and the stockholders of the railroad companies."

"There is a danger that this feeling of selfishness may lead them too far and reduce this compensation so much that it will not enable the railroads to serve them with efficiency—to keep up their roadbed, culverts, bridges, and everything so that they will be entirely safe for the transportation of passengers and freight, and to keep the rolling stock in the best state of efficiency and enable them to provide the best service attainable, and that is exactly what those corporations are required to do. They are required to exercise the highest degree of care in relation to the transportation of passengers, and a high degree of care in relation to the transportation of freight, and it is certainly for the interests of the people that they should be enabled to do this; and it would be a very short sighted policy which would reduce the compensation of these railroads to a degree that would disable them from performing these services fully and fairly for the benefit of the people."

It was not until 1909, however, that the Supreme Court of the United States recognized the character of depreciation and the necessity for collecting an allowance to cover it as it accrues. This recognition appears in the decision handed down by Mr. Justice Moody, in what has come to be known as the Knoxville case. (City of Knoxville *v.* Knoxville Water Co., 212 U. S., 1, decided January 4th, 1909.)

This decision, here quoted somewhat at length, holds that, not only is it proper to set aside periodically an allowance to cover the accruing loss of value of aging property, but that it is the plain duty of operating companies so to do and to collect, from the public served, enough to maintain at all times the value of the investment unimpaired.

It also holds that though the cost of reproduction is one way of ascertaining the present value of a plant, like that of a water company, which has been in use for many years, the test would lead to obviously

incorrect results if the cost of reproduction is not diminished by the depreciation which has come from age and use.

"The cost of reproduction is one way of ascertaining the present value of a plant like that of a water company, but that test would lead to obviously incorrect results, if the cost of reproduction is not diminished by the depreciation which has come from age and use. The company contends that the master, in fixing upon the valuation of the tangible property, did make an allowance for depreciation, but we are unable to agree to this. The master nowhere says that he made allowance for depreciation, and the language of his report is inconsistent with such a reduction. The figures which he adopts are those of a 'fair contractor's price.' The basis of his calculation was the testimony of an opinion witness called from the company. That witness submitted a table, which avowedly showed the cost of reproduction, without allowance for depreciation. The values testified to by him were adopted by the master in the great majority of cases. The witness's valuation of the tangible property was somewhat reduced by the master, but the reductions were not based on the theory of depreciation, but upon a difference of opinion as to reproduction cost.

"The cost of reproduction is not always a fair measure of the present value of a plant which has been in use for many years. The items composing the plant depreciate in value from year to year in varying degree. Some pieces of property, like real estate for instance, depreciate not at all, and sometimes, on the other hand, appreciate in value. But the reservoirs, the mains, the service pipes, structures upon real estate, standpipes, pumps, boilers, meters, tools and appliances of every kind begin to depreciate with more or less rapidity from the moment of their first use. It is not easy to fix at any given time the amount of depreciation of a plant whose component parts are of different ages with different expectation of life. But it is clear that some substantial allowance for depreciation ought to have been made in this case. The officers of the company, *alio intuituo,* estimated what they called 'incomplete depreciation' of this plant (which we understand to be the depreciation of the surviving parts of it still in use) at $77 000 which is 14 per cent. of the master's appraisement of the tangible property.

"A witness called by the city placed the reproduction value of the tangible property at $363 000, and estimated the allowance that should be made for depreciation at $118 000, or 32 per cent. In the view we take of the case, it is not necessary that we should undertake the difficult task of determining exactly how much the master's valuation of the tangible property ought to have been diminished by the depreciation which that property had undergone. It is enough to say that there should have been a considerable diminution, sufficient at least to raise the net income found by the court above 6 per cent. upon the whole valuation thus diminished.

"The company's original case was based upon an elaborate analysis of the cost of construction. To arrive at the present value of the plant, large deductions were made on account of the depreciation. This depreciation was divided into complete depreciation and incomplete depreciation. The complete depreciation represented that part

of the original plant which through destruction or obsolescence had actually perished as useful property. The incomplete depreciation represented the impairment in value of the parts of the plant which remained in existence and were continued in use. It was urgently contended that, in fixing upon a reasonable return, the amounts of complete and incomplete depreciation should be added to the present value of the surviving parts. The court refused to approve this method, and we think properly refused. A water plant, with all its additions, begins to depreciate in value from the moment of its use. Before coming to the question of profit at all, the company is entitled to earn a sufficient sum annually to provide, not only for current repairs, but for making good the depreciation and replacing the parts of the property when they come to the end of their life. The company is not bound to see its property gradually waste, without making provision out of earnings for its replacement. It is entitled to see that from earnings the value of the property invested is kept unimpaired, so that at the end of any given term of years the original investment remains as it was at the beginning. It is not only the right of the company to make such a provision, but it is its duty to its bond and stockholders, and, in case of a public service corporation at least, its plain duty to the public. If a different course were pursued, the only method of providing for replacement of property which has ceased to be useful would be the investment of new capital and the issue of new bonds or stocks. This course would lead to a constantly increasing variance between present value and bond and stock capitalization—a tendency which would inevitably lead to disaster, either to the stockholders or to the public, or both. If, however, a company fails to perform this plain duty and to exact sufficient returns to keep the investment unimpaired, whether this is the result of unwarranted dividends upon over-issues of securities, or of omission to exact proper prices for the output, the fault is its own. When, therefore, a public regulation of its prices comes under question, the true value of the property then employed for the purpose of earning a return cannot be enhanced by a consideration of the errors in management which have been committed in the past."

This decision has been supported in all subsequent decisions of the United States Supreme Court having to do with the matter, and therefore it stands to-day the law in this country. Questions of interpretation have been raised by public utility owners, lower Courts have not all followed the decision literally, and there are certain practical questions arising in connection with the determination of depreciation in the valuation of a property, all of which require careful consideration and will be discussed in this chapter.

Depreciation being defined primarily as loss of value or worth, the depreciation that is of concern in valuation proceedings is that which is measured by the sum that should be deducted from original cost to date or from estimated cost of reproduction new, as a step in finding that which the Courts have called "fair value." The Committee will call this the "depreciation of valuation", or "fair depreciation".

Three Aspects.

The Committee will consider depreciation from three aspects:

1.—The cause—*decretion or loss of service life* of physical property;
2.—The record—*accounting depreciation;*
3.—The amount sought—the *depreciation of valuation,* or *fair depreciation.*

By "decretion" is meant that loss of service life of a physical property, or property unit, or item, which may be estimated by an inspection of the property, considering the history of its past service and the probable character of its future service, the method and character of its maintenance, and all other pertinent facts concerning it. It is the fact of loss of service life, regardless of its effect on value or anything else. Consciously or unconsciously, the result will be expressed as a fraction of the estimated total service life (elapsed life plus expectation of life) of the property, or property unit, or item, and this must be converted into a corresponding fraction of cost, in order to find the loss of value resulting from the decretion. Some minds may not consciously go through the elementary process, but will estimate at once the final money sum.

By "accounting depreciation" is meant that sum which, in the bookkeeping of the owners of the property, has been charged to operating expense and deducted from the capital, either directly or by setting up a reserve, to allow for an estimated or actual depreciation of a property unit or item. A definition conforming to methods prescribed by the Interstate Commerce Commission is the sum charged to operating expense to provide a reserve* to cover the cost less salvage of a given property when it is retired from service. Accounting depreciation may or may not be equivalent to the actual or *fair depreciation* at any time. Whether or not it is approximately equivalent, will depend on the methods used and the accuracy of the forecast of service life of the property units or items.

The "depreciation of valuation" or "fair depreciation" has been defined above.

In valuation discussions, depreciation cannot be treated wholly independently of its cause or of accounting methods, but, so far as possible, the Committee will consider: first, only decretion or the cause; second, only accounting depreciation; and, third, the depreciation of valuation.

Decretion.

Causes of Decretion.—Decretion may be due to use. A machine may have been purchased new, may have been in use a year, may show no signs of wear, and yet experience tells that the machine when new

* For a definition of this term, see p. 1858.

was probably good for only 10 years. One of these years has elapsed; the machine is as valuable in its present output of service as ever it was, but, a year of its life has gone into service, and hence, approximately one-tenth of the life of the machine must be estimated as gone, and therefore decretion exists to that extent. Examination of the particular machine may lead the examiner to estimate that it has still 11 years of service before it, in which case its total life will be estimated at 12 years, and only one-twelfth of its service life will be gone. Examination always should be made, and consideration should be given to the character of past and probable future service, and the method and character of maintenance, because, on all these will depend the estimate of total service life. Units of service may be of more consequence than years of service in estimating service life.

Decretion may be due to age alone, as some properties grow old regardless of the use to which they are put. Sometimes this aging depends on the care given the properties. Wood decays, iron oxidizes, brick disintegrates, even stone is destroyed by the elements, some kinds more rapidly than others. The particular use to which these substances are put, whether in sheltered or exposed situations, may determine the rate of decretion, which for some uses may be practically or actually nil, within the range of human estimates. The effect of weathering often may be overcome by periodic repairs, and a given structure may remain in use for many years, and even perpetually, the structure of a given day having in it no item that was in it when it was first built. Such structures will always show some physical deterioration—the immediate or approaching need of some replacements or repairs.

Decretion may be due to immediate or approaching inadequacy. A given machine may be doing a work of constantly increasing magnitude which now or later will require a larger machine before the present one is worn out. The present machine may be good for a considerable service within its capacity. It may have, therefore, a large salvage value, but, for the purpose for which it is being used, it is approaching the end of its service life.

Decretion may be due to obsolescence. A machine may belong to a class that is more or less rapidly changing patterns and forms, due to an advancing art or science. Long before it is worn out, new forms may have been devised which are so much more efficient that it may no longer pay to keep the old machine in service. Or advancing civilization, growth of population, and changing character of social life may call for a different service from that rendered with satisfaction to the people served under the old conditions. This sort of decretion is not due to inadequacy, but to obsolescence.

The several causes mentioned may exist singly or together in a given plant, or plant unit.

Decretion of a plant unit may also be caused by accident.

Decretion always Present in a Going Property.—Decretion is likely to exist in almost every physical item of a going property except land. Even the Pyramids are slowly passing away, and, between items of very long life and those, like working tools, of very short life, there are all degrees of length of service life. Some properties, like water-works or gas properties, are essentially all new when they begin to operate, because, though some pipes may have been in the ground for some time, their total service life is so long that this preliminary exposure to decay may be neglected. Shortly after a water or gas property begins to operate, its machinery and structures have begun to deteriorate, and could not be inventoried as new, even for the purpose for which they are used, although they may be giving just as efficient service as new machinery and structures could give. Other properties, like railroads, have some items that are essentially old when regular service begins. Ties, for instance, begin to decay with some rapidity as soon as they are laid in the track, and often by the time a newly created extensive property has reached the operating stage they are being replaced almost or quite at the usual normal rate on the older part of the road.

Due to these facts, no going property could ever be inventoried as new if taken item by item or unit by unit, because some of the service life of practically every item or unit will have passed. As a result of this fact it can be shown that when the properly weighted average of all the decretion of the various units of a well-maintained railroad, for instance, is found, the railroad property as a whole cannot show more than from 80 to 90% of new condition, or there is estimated, say, 15% loss of value due to decretion of various units.

The Troublesome Problem.—Although, in a well-maintained property, decretion is always present in some degree, yet in some cases this decretion, converted into loss of value, should not be considered to be a deductible quantity in finding the value of the property—that is, it should not be considered as depreciation of valuation, or fair depreciation. Unfortunately, this has not been entirely understood.

Whether or not, and to what extent, if any, the loss of value due to existing decretion shall be deducted from original cost to date or cost of reproduction new, when finding fair value for any purpose, is the great troublesome problem of depreciation in valuation. This problem will be discussed after explaining accounting depreciation.

Accounting Depreciation.

General Statement.—To understand accounting depreciation, as defined in the Glossary, it is necessary to know something of the fundamentals of methods of accounting for depreciation. Bringing

depreciation into the accounts of a company owner is one of the steps necessary to keep the earnings and property statements correct.

Many owners have not understood, and some do not now understand, the necessity for charging off depreciation as it accrues. Sooner or later, such owners are brought face to face with the necessity of renewing plant units with no means available, because profits have been over-estimated and a part of the capital has been distributed in the past by reason of the failure to account, as it progressed, for depreciation, which though not apparent, was nevertheless accruing.

Moreover, with respect to public service properties likely at some time to be valued for purchase, or the settlement of some rate or other public question by a regulating body, or a Court, the owner may find the Knoxville decision troublesome, tending to prevent a finding of the real value of his property, if he has not been careful to account for depreciation as it has accrued.

There are various methods of accounting for depreciation. In many cases the method is prescribed by a public regulating body. When it is not thus prescribed, the method applicable to any given property may depend on the law, or, with different methods conforming to the law, on fairness or convenience. What is fair or convenient may depend in part on the character of the property to be accounted for, whether made up of long- or short-lived items, whether stationary, growing rapidly or slowly. The method to be adopted for a given property should accord with a reasonable interpretation of law, and sound business principles.

Fundamental Principles.—

1.—The owner of a public utility is under obligation to the investors in its securities to maintain the integrity of the investment.

2.—The public is under obligation to the utility owner to pay a fair price for the service rendered and to meet fairly its other contractual obligations fairly. Of concern in the present discussion is the obligation to include, in the fair price for service, an allowance for the maintenance of the integrity of the investment; that is, an allowance to cover the gradual destruction or deterioration, including estimated inadequacy and obsolescence, of the physical property as this occurs. This means that when, for any ordinary reason, an item of physical property is retired, a sum equal to its cost, or some equivalent of this sum, paid by the people who have been served, should be in the hands of the company owner to make good the loss due to the retirement of the item.

It is immaterial to the maintenance of the service how this is paid by the people, whether in a lump sum when the item goes out of service, or a little at a time, more or less in proportion to the gradually lessening service life of the item; but law or convenience may dictate the

manner of payment. As a matter of convenience, and of fairness to the using public and the owner, those methods of payment should be adopted which, conforming to law, avoid great irregularities in operating expense, in dividends, or in rates for service—that is to say:

3.—The return to the investor and the rates to the consumer should be kept reasonably stable and uniform from year to year, and should be fair.

The respective obligations of the public and the corporation are set forth in numerous Court decisions; the obligations of the utility to the investors in its securities are plainly stated in the Knoxville case.

Classification of Property Units.—Simplicity of accounting requires the use of different methods for different property units. It will be plain, perhaps, that the cost of such property as fuel, oil, waste, and supplies in general, which one can see are consumed in quantity from day to day and from hour to hour, do not represent investment, as the term is generally used, but operating expense; and such property used during any fiscal period should be paid for by the public during that period. The usual fiscal period is a year, and it may be said fairly that the cost of any property used up during a year is properly a part of operating expense.

This reasoning would apply also to parts of units, such as tubes of boilers, tires on locomotive driving wheels, shingles on buildings, etc., the replacement of which, though not occurring annually, may be classed as repairs rather than as renewals. The units are not retired, they are only repaired. All replacements that properly may be called repairs may without question be provided for in operating expense.

Closely allied to fuel and other supplies, but really representing investment, are certain other classes of property, like telegraph poles, railroad ties, etc. These last for a number of years, but not all of any kind last the same number of years, and a condition gradually comes about, in a stationary or slowly growing property, that calls for a renewal of a certain fairly regular percentage of all the poles or all the ties each year. The maintenance of the normal condition of poles or ties, which condition is necessarily less than new, properly may be charged in operating expense. The depreciation actually accruing during any year is offset approximately by equivalent expenditures for renewals. Simplicity of accounting does not "require" this method of handling tie accounts, but they have nevertheless been handled in this way. The integrity of the original investment, if that is measured by the service life of physical items, is not maintained by this method, because initial depreciation is not made good.

The difference between normal condition and condition new, of such items as have been mentioned above, may be called initial decretion, producing what is sometimes estimated as depreciation. Ap-

parently, under a strict interpretation of the law, such initial depreciation must be lost to the owner in a valuation unless:

1.—He has collected an adequate allowance for depreciation from the beginning; or
2.—The whole thing is ignored as not reducing the value of the property as a going concern; or
3.—It is considered that this depreciation is a development cost which, added to the other costs, will offset itself when full depreciation is estimated.

Forming a link between such property, as ties and poles and the next distinct class to be mentioned below, is such property as the rolling stock of a great railroad. The items are much larger than the separate ties, but the aggregate yearly expenditures for renewals may be not more than those for ties, and in the past the cost of renewals has been put into operating expense as the renewals occurred, under the head of repairs and renewals; but it may be met just as well by moneys taken from a fund, maintained by sufficient annual contributions for depreciation from the patrons of the utility, or by new capital furnished by the owner in lieu of that contributed by the patrons as depreciation allowances, but invested otherwise in the property by the owner. The Interstate Commerce Commission now requires that reserves be set up for the rolling stock of railroads, but, with respect to initial depreciation existing before such reserves were established, when retirements were handled as operating expense, the owners are situated exactly as they are with respect to ties, and they must lose such depreciation in a valuation unless the commissions or Courts will accept in their favor one of the two alternatives last mentioned in the foregoing paragraph.

Theoretically, the public contributes only the cost of the items retired. The items purchased in place of these may cost more or less than the items retired. Only the cost of the items retired should be charged against the depreciation contributions, and this should be charged, whether or not a new item is purchased.

The depreciation of certain other property units, as the very large and costly structures of a great railroad, the cast-iron pipe lines, or the pumping engines of a water-works property, the buildings, pipe lines, and holders of a gas property, etc., all having long life, and some of them involving, for the maintenance of the service rendered, relatively large expenditures at irregular intervals, can be provided for best without question by regular annual allowances established for the purpose, and accruing from year to year for each item somewhat in proportion to the spent life of the item. If proper accounting is provided, it is immaterial, except as a matter of public policy and economy, whether the allowances for any particular item be held as

cash at interest or as convertible securities until that item is retired, or be invested in additions or betterments to the property. In either case the integrity of the investment is maintained.

The Replacement Method.—The replacement method is an accounting method which provides that the owner shall be reimbursed for the cost of a property unit at the time it reaches the end of its service life and is retired. That is, the cost is charged to operating expense at that time. Operating expense being collected from the public, it is said that the owner is reimbursed when the charge to operating expense is made. Some owners do not charge the cost of the retired item, but rather the cost of the item which replaces it—if such there be—which may be more or less than the cost of the item retired. If it is more, the public is contributing capital to this extent; if less, the owner is losing capital to this extent. This practice is prohibited by the Interstate Commerce Commission for large telephone companies, although permitted for many classes of railroad property.

The replacement method is the most convenient one to use for some short-lived property units, but, under a possible interpretation of the law as laid down in the Knoxville case and the Minnesota rate cases, the method is not strictly applicable to any wasting property units, because it seems not to keep the investment intact at all times. However, the method should be legally proper for railroad use for all units except equipment, because the regulating body, the Interstate Commerce Commission, has sanctioned it, and the Committee believes that a proper interpretation of the Knoxville decision would also permit the use of the method in some other cases, certainly to the extent that replacements may be properly classed as current repairs. For the language is to the effect that the public utility "is entitled to see that from earnings the value of the property invested is kept unimpaired," and that: "before coming to the question of profit at all, the company is entitled to earn a sufficient sum annually to provide not only for current repairs, but for making good the depreciation and replacing of parts of the property when they come to the end of their life."

To explain the method more fully, let railroad ties be considered: They are an elementary part of the unit known as track, and, in estimating cost, would be an item in the inventory. If an old track is properly maintained, about the same percentage of the ties will be replaced with new ones each year—ties will not all disappear and be replaced at once. In the beginning they were all new, though, in the case of a railroad of magnitude built in one operation, some of the ties first laid will have reached nearly the ends of their lives by the time the whole line is completed. What will come about with such a road will be a condition such that at any given time there will be some ties ready to be replaced, some new ties that have just been put in, and perhaps approximately equal numbers in all stages of

life, so that the whole would inventory about 50% of new condition. Ties never can be much better than this nor much worse in an old, well-maintained track. In northern latitudes they may be a little under normal in the spring, just before renewals begin and a little above normal by the end of the summer, when renewals for the season have been completed. Ties in such track are kept in normal condition with respect to investment and service if they are kept in about 50% condition by annual renewals accounted for in operating expense. This is not exactly true when there is much recently added new track, but relatively small additions do not greatly disturb the balance.

When property is maintained in this way it is said to be maintained under the replacement method of accounting; theoretically, the cost of the old item is charged off, that is, credited to capital and charged to operating expense, and the cost of the new item is charged to capital when the replacement is made, and no accumulating depreciation allowances are provided or needed. Really, no entry need be made in the capital account unless the new item is cheaper or more costly than the old, and, in the matter of ties, is not made usually in any event, ties being considered much like fuel.

It has frequently been insisted that allowances for depreciation are strictly for the purpose of making replacements, and from this point of view property units retired without being replaced would not be provided for by the replacement method, but, in modern accounting, a unit which is retired and not replaced is, and in equity should be, treated in the same way as if it were replaced. That is, its cost should be made good to the owner, and is made good by charging it to operating expense.

Before describing other methods of accounting, an effort will be made to distinguish between depreciation reserve and depreciation funds, and to state the depreciation theories on which accounting methods are based.

Depreciation Reserve vs. Depreciation Fund.—Depreciation reserve and depreciation fund are two entirely distinct and separate things which are frequently confused, largely because of the loose terminology used in the past by accountants, valuation engineers, Courts, and commissions, all of whom have used the terms interchangeably, and have sometimes increased the confusion by speaking of either as the "depreciation reserve fund." The depreciation reserve represents merely the result of a series of entries on the books, made for the purpose of preventing overstatement of earnings or property, as will be explained later; but a fund is money or its equivalent set aside to be devoted to some particular purpose, a depreciation fund being set aside to provide for depreciation of property.

On the balance sheet of any enterprise, various items of assets appear, and among these will be the value of the property. If this property is carried at its full original value or cost on the asset side,

but has been in service some time and has lost some of its value, this fact should appear on the balance sheet in some way, or the actual value of the property on any given date will be over-stated by the amount of the depreciation. Hence, in modern bookkeeping the item of depreciation reserve appears on the liability side of the balance sheet, which makes the property showing, at least so far as the effect of depreciation is concerned, correct, provided the depreciation has been properly estimated. This same result could be achieved by simply writing off a certain part of the value of the property, carrying the property on the asset side at its depreciated or written-off value and making no entry on the liability side of the balance sheet. This, however, is not considered to be as valuable a method from an historical standpoint as that which carries property at its full value on the asset side and sets up a reserve on the liability side of the balance sheet to allow for the depreciation.

When a depreciation reserve is established for the balance sheet, one or more depreciation reserve accounts are carried in the ledger. As illustrating the use of the depreciation reserve accounts, let it be supposed that a certain item of property has depreciated $100 during a given year, and that no cash has been expended for it, nor is any expenditure to be made immediately. Although no expenditure is to be made immediately, or has been made, the fact of the depreciation means the consumption of $100 of invested capital, and, unless an entry is made to show this, the net revenue for the year will be over-stated. Therefore, although no cash is spent, the operating expense account is charged with $100; but, operating expense being charged with $100 which is not spent, a surplusage of cash or its equivalent to the amount of $100 will be found. To offset this and prevent the over-statement of the assets, the depreciation reserve account will be credited with $100. As time goes on, the item will continue to depreciate, and the depreciation will be charged periodically in operating expense and credited to the reserve account, until finally the item will be retired. At this time, assuming that it has no salvage value, it will be written off from the property statement on the asset side of the balance sheet, and at the same time its value must be taken from the reserve in order still to preserve proper balance. Therefore, the reserve will be charged with the whole value of the item, which, if the estimates of depreciation from time to time have been correct, will be just equivalent to the sum of the credits to depreciation reserve for this item.

Whenever a charge is made against operating expenses for depreciation, the depreciation reserve account is credited. When property is retired, the cost new less salvage recovered is charged against the depreciation reserve. At any given date, therefore, the amount that should appear in the depreciation reserve on the balance sheet would be a summary of the credit balances of the various depreciation reserve accounts appearing in the ledger. If the estimates made for

depreciation from time to time happen to agree with the fact, the amount standing in the depreciation reserve item on the balance sheet at any time will represent the accrued depreciation in the property, but this is likely seldom to be the case.

The depreciation reserve exists in modern bookkeeping, whether or not there is a depreciation fund. The depreciation fund is a part of the assets, and is established merely by charging the fund and crediting cash or some other asset item with any amount that at any time may be deemed proper. This double operation does not disturb or change the amount of the assets, but merely changes the names under which they are carried.

It should be borne in mind that the setting aside of assets in a depreciation fund is not charging depreciation. This is accomplished only by making a charge against operating expenses and so decreasing the showing of net earnings. Depreciation is not provided for until it is charged in operating expense, and it is not deducted from the property until it is credited to depreciation reserve, or written off from the property statement on the asset side.

Practically, of course, collection may be made from the public without any depreciation entry in the books, that is, enough may be collected in rates to pay operating expense, depreciation, and fair return, but that part which should be applied to the property to cover depreciation may be otherwise disposed of, as, for instance, distributed as unwarranted dividends; and, when this is done wittingly, a theft has been committed from the property, and, when done unwittingly, error of management is shown. The argument in the foregoing paragraph assumes an honest and proper management.

Under the replacement method of accounting, there would be neither depreciation reserve nor depreciation fund, the reserve being established only when operating expense is charged without expenditure of cash, and under this method at any time the property will be over-stated by the amount of the depreciation accrued but not yet realized through retirements.

If no charge is made to operating expense or credit to reserve for depreciation of an item previous to its abandonment, but specific assets are set aside as a fund to offset the accruing depreciation of the item, "depreciation fund" will appear among the assets, but, as before, the profits and the property will be over-stated at any time by the amount of depreciation accrued but not realized by retirement.

Depreciation Theories.—Depreciation of physical units used in connection with public utilities, or, indeed, with any other industries, does not proceed in accordance with any mathematical law. One unit, identical with another, and used for the same purpose in the same way, goes out of service before the other, perhaps because of some accident; or a unit goes out of service before it is worn out,

because of some new invention that displaces it, or some new requirement of service that makes its use no longer possible; another unit, performing hard service, requires so much more repair during its later than during its earlier life, and yields so many fewer units of service per unit of time, that, long before it is actually worn out, it becomes uneconomical to use it, and it is replaced some time before it is incapable of service. There is no regularity in the development of the increasing need for repairs; there is no regularity in the progress of depreciation; but, in order to devise a reasonable plan for laying aside allowances from year to year to make good the depreciation as it accrues, and to provide for the accumulation of a sum equivalent to the cost less salvage of a unit by the time it is retired, some theory of depreciation progress must be assumed on which such allowances may be based. Several such theories have been suggested, and corresponding accounting methods have been developed for some of them and have been adopted by accountants and approved by Courts and commissions. Three of the more generally mentioned theories will be explained, namely: The straight-line theory, the compound-interest theory, and the unit-cost theory; and the corresponding accounting *methods* will then be discussed.

The Straight-Line Theory.—The straight-line theory assumes that depreciation progresses uniformly from the beginning of service to the end of service life; that when service life is half gone, value less salvage is half gone, when service life is nine-tenths gone, value less salvage is nine-tenths gone. Thus, if a unit cost \$100 and has a salvage value of \$10, after an estimated total service life of 10 years, and has been in service for 5 years, it has depreciated in value one-half of \$90, or \$45, and is worth \$45 plus \$10 salvage, or \$55; if it has been in service 9 years, it has depreciated \$81 and is worth only \$19. This is the simplest depreciation theory, and because of its simplicity it has been widely adopted. Its application in accounting and valuation is sometimes attended with certain apparent inequities which will appear in the discussion of accounting under this theory.

The Compound-Interest Theory.—This theory assumes that depreciation progresses at the same rate as a sinking fund grows from an annuity accumulating at compound interest. Thus, if a unit cost \$100 and has a salvage value of \$10 after a total service life of 10 years, an annuity may be determined such that, with its accumulation of interest, it will equal \$90 at the end of 10 years, and the depreciation of the unit at the end of any year will be equivalent to the accumulation of the annuity and its accretions to that time. If the rate of interest be r; the cost less salvage of a unit be C; and the estimated service life N years; the annuity necessary to set aside to equal C in N years is given by

$$A = \frac{C\,r}{(1 + r)^N - 1} \dots\dots\dots\dots\dots\dots\dots (1)$$

and the sum to which this will amount in n years is given by

$$S = \frac{C[(1 + r)^n - 1]}{(1 + r)^N - 1} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

This may be solved by logarithms, or the result may be taken from amortization tables, many of which have been published covering Equations (1) and (2). In applying these equations to a particular example, let it be assumed as before that a service unit costs $100, has a salvage value of $10 after a total service life of 10 years; that it has served 5 years, and that interest is at the rate of 5 per cent. Then $90 must be accumulated in 10 years, and the necessary annuity, A, at 5% is $7.16. This annuity, with its accumulation of interest, will amount to $39.54 in 5 years, and the unit is then worth $50.46 plus $10.00 salvage, or $60.46. After 9 years of service, the depreciation amounts to $78.90, and the unit is worth $11.10 plus $10.00 salvage, or $21.10. The depreciation during any one year is equivalent to the annuity for that year plus the interest on the accumulation of previous annuities and interest.

This theory may have a certain practical advantage over the straight-line theory when applied to newly created properties, because it requires the setting aside of a less sum to offset accruing depreciation in the earlier years of the enterprise, when expense is likely to be relatively high and income relatively low. On the other hand, when applied to a unit for which the cost for repairs and upkeep is much greater toward the end of its life than at the beginning, this theory bunches the larger deductions from income for repairs and depreciation; and the straight-line theory would tend to produce less inequality in the deductions throughout the years of service life, so far as this influence is concerned.

With some units, such as locomotives, the expense for repairs is so large that the depreciation deduction is relatively insignificant and, so far as inequality of deductions is concerned, it is of less consequence which theory is adopted than it is when units like water pipe are under consideration, because the item of repairs on such units is relatively insignificant when compared with the accruing depreciation.

The discrepancy between accrued depreciation under the straight-line theory and under the compound-interest theory is much greater when the units are long-lived than when they are short-lived. Thus, a 10-year unit having no salvage value loses half its value in 5 years under the straight-line theory, regardless of the rate of interest, and at 5% under the compound-interest theory it loses nearly as much—about 44% of its value in the same time (45.1% at 4% and 41.6% at 7%); but a 50-year unit, losing half of its value in 25 years, under the straight-line theory, loses only 22.8% of its value at 5% under the

compound-interest theory. It will be shown later, however, that the total cost for service during the service life of a property unit, including interest on the value in the unit, depreciation annuity or allowance, and interest on both these annual costs, is exactly the same under one theory as under the other, and indeed is the same as under the replacement method of maintaining property already described, but, notwithstanding this equality, the theories are not equally applicable to all classes of property, as will also be shown later.

The Unit-Cost Theory.—This theory holds that the depreciation of a service unit at any stage of the service life is the difference between what it cost new and what could be paid for it in its depreciated condition without increasing or diminishing the cost per unit of service during its remaining service life. In other words, it is equivalent to the difference in worth of two units which would perform the same service at the same total cost per unit of service, one having an estimated service life equal to the total estimated service life of the unit under consideration, and the other an estimated service life equal to the estimated remaining service life of the unit. Comparing the relative economy of two such units in general, the engineer solves a question like this: If Unit A costs \$100 and lasts 20 years, how much can be paid with equal economy for Unit B for the same service, if it will last but 10 years? The costs must include all costs necessary to put the units in place and at work. The estimate should include consideration of the effect of the lessened output of service and greater cost for operation and repair of the units, as they draw near the ends of their lives; but this effect is sometimes ignored. When excluded, the "unit-cost theory" becomes the "compound-interest theory", which, therefore, may be considered to be a special case of the "unit-cost theory". On the basis of this theory of difference in worth, considering Unit A as the unit new and Unit B as the depreciated unit, a formula for the present worth of the depreciated unit is developed thus, ignoring output and cost of operation and repairs: The two units are compared on the basis of equal annual cost for interest and depreciation annuity. If C be the cost new of Unit A and c the present worth of the depreciated unit, B; r the rate of interest; N the estimated service life of A; and n the estimated service life of B; the total annual costs for interest and annuity will be:

$$\text{For } A \ldots\ldots \text{Interest, } C\,r, \ldots\ldots \text{Annuity, } \frac{C\,r}{(1+r)^N - 1}$$

$$\text{For } B \ldots\ldots \text{Interest, } c\,r, \ldots\ldots \text{Annuity, } \frac{c\,r}{(1+r)^n - 1}$$

Making these two equal and solving for c gives

$$c = C\,(1+r)^{N-n}\,\frac{[(1+r)^n - 1]}{[(1+r)^N - 1]}$$

and $C - c$ would be the depreciation during $N - n$ years, which will be found to be identical with the S of Equation (2), if $(N - n)$ be substituted for n in that equation. This is the compound-interest theory.

If the items of increased cost of operation and repairs be included, the application of the unit-cost theory becomes quite complex. The comparison is made in the same way by making total annual costs equivalent, but the annual cost is first reduced to cost per unit of service by dividing by the estimated output capacity of the new and depreciated property units. Thus, if A and a are costs of operation and repairs for the longer- and shorter-lived units (new and depreciated units), respectively; C and c the respective costs, C being the actual or estimated cost of the new unit of longer life and c the price that could be paid for the shorter-lived (depreciated) unit to produce the same cost per unit of service; B and b the respective depreciation annuity multipliers of C and c under the sinking-fund theory; if D units of service may be realized annually from the longer-lived (new) unit and d units from the shorter-lived (depreciated) unit; and if r be the rate of interest, the following equations of annual costs may be written:

$$\frac{A + B\,C + r\,C}{D} = \frac{a + b\,c + r\,c}{d}$$

Solving this equation for c, the price that could be paid for the shorter-lived (depreciated) unit is found to be:

$$c = \frac{\frac{d}{D}(A + B\,C + r\,C) - a}{b + r}$$

The difference between C and c is the accrued depreciation at the date of estimate. The amounts of B and b may be obtained from

$$B = \frac{r}{(1 + r)^N - 1}$$

and

$$b = \frac{r}{(1 + r)^n - 1}$$

or from amortization tables. The capacities, D and d, of the new and old units should be their actual or estimated capacities for service under normal conditions, not the respective outputs under varying business conditions which might readily make the older unit more valuable than the newer one.

The compound-interest theory produces, in its application in accounting, equal annual charges for the sum of interest and depreciation allowances, while the unit-cost theory is based upon equal

annual charges for the sum of interest, depreciation allowance, and operating expense (including repairs) *per unit of output.* This theory is probably the soundest theory of depreciation, and, when applied with intelligence, probably furnishes the truest measure of accrued depreciation. It is not readily applicable to accounting purposes, because its formulas cannot be tabulated, but it may be used for the purpose of checking the results of the application of other theories and for finding the accrued depreciation of any property at any time, in connection with a public valuation, when there has been no proper accounting in the past, or for finding remaining value for the purpose of inaugurating a proper accounting system for an old property.

Methods of Accounting Applicable to the Straight-Line and Compound-Interest Theories of Depreciation.

This discussion will be approached from the standpoint of the proper payments of the public to company owners and the proper disposition of these payments by the company owners, rather than from the standpoint of the bookkeeping methods of the company owners. It should be remembered here that it is the duty of the public served to pay operating expense incurred in its service, interest on capital invested for its service, and the cost of property consumed in its service; but operating expense is omitted from this discussion as being independent of the other two items, which are to some extent mutually dependent on each other, and because it is only depreciation accounting that is now under consideration.

Accounting Under the Straight-Line Theory.—Under this theory the public will pay the full amount of the depreciation as it accrues, a certain uniform fraction of the whole cost, less salvage value, of any unit each year of its life, and, paying this each year, thus returning a part of the invested capital, it should pay a correspondingly decreased interest on invested capital each succeeding year. A tabular statement of a particular example will illustrate: A certain unit costs $100, has a life of 20 years, and no salvage value. The cost or book value in the unit and the payments of the public with interest at 5% are shown in Table 1.

Remembering that the property must be considered to be a continuing property and that the company owner is bound to preserve the integrity of the investment, it must be clear that the allowances paid by the rate-payers belong to the property and must be considered to be a part of it. If taken out of the property, the investment is impaired, and if paid to the stockholders, then, although they lose nothing, the bondholders' security is reduced, and the public and later stock purchasers are not protected against the gradual destruction

of the property that should be a continuing property. Practically, therefore, the depreciation allowances paid by the rate-payers must be considered a part of the property, not to be distributed to the stockholders, but to be kept in the property in some form, in order to preserve the integrity of the investment.

TABLE 1.—Illustration of the Straight-Line Method.

Showing Book Value and Payments by the Public on Account of Fair Return and Depreciation.

Property Unit Costing $100.00, Lasting 20 Years, No Salvage Value, Interest at 5 Per Cent.

(1) Age.	(2) Remaining value at end of year.	(3) Depreciation allowance.	(4) Return on remaining value, 5%.	(5) Combined depreciation and return, 5%.
0	$100.00			
		$5.00	$5.00	$10.00
1	95.00			
		5.00	4.75	9.75
2	90.00			
		5.00	4.50	9.50
3	85.00			
		5.00	4.25	9.25
4	80.00			
		5.00	4.00	9.00
5	75.00			
		5.00	3.75	8.75
6	70.00			
		5.00	3.50	8.50
7	65.00			
		5.00	3.25	8 25
8	60.00			
		5.00	3.00	8.00
9	55.00			
		5.00	2.75	7.75
10	50.00			
		5.00	2.50	7.50
11	45.00			
		5.00	2.25	7.25
12	40.00			
		5.00	2.00	7.00
13	35.00			
		5.00	1.75	6.75
14	30.00			
		5.00	1.50	6.50
15	25.00			
		5.00	1.25	6.25
16	20.00			
		5.00	1.00	6.00
17	15.00			
		5.00	0.75	5.75
18	10.00			
		5.00	0.50	5.50
19	5.00			
		5.00	0.25	5.25
20	0			
Totals........................		$100.00	$52.50	$152.50

The allowances, being part of the property, ought to earn at the same rate as the capital remaining in the property. That is, persons having invested in a given property do not wish the investment continually to vary either in amount or return rate, they desire that the investment shall remain and shall earn at a uniform rate. The allowances may be made to earn at the same rate as the remaining property, if reinvested immediately in the property; they may earn at an even greater rate, if fortunately invested otherwise; or they may and probably will earn at a less rate, if placed in bank. Immediate investment in the property itself, which should insure a continuance of the full rate of return, may not be possible, often will not be when a property is not rapidly growing, and lack of opportunity for other investment may require the banking of allowances. It would seem, therefore, that the public should make up the shortage in return, if any there be. Theoretically then, proper accounting, under regulation that determines fair return by which full return on the entire investment is secured, would charge to operating expense any deficiency of return on allowances and credit to income any excess of return over the fair rate.

When only a single item is considered, this method, as the table shows, makes payments from year to year ununiform, with much larger payments in the beginning than toward the end, which is undesirable unless repairs are enough greater toward the end to equalize the payments. When there are many items of varying ages and expectations of life, this defect largely vanishes. This is not a defect of the accounting, but a necessary result of using the straight-line theory of depreciation.

Accounting Under the Compound-Interest Theory.—Under this theory, the public pays interest on the invested capital and depreciation as it accrues, according to the compound-interest theory, but there are different ways of considering these payments and distributing them in the accounting, leading to two or more different methods of accounting. The Committee will discuss two methods, namely: 1, the compound-interest method, heretofore called the equal-annual-payment method, and 2, the sinking-fund method.

1. *The Compound-Interest Method.*—Confining the discussion to a single unit without salvage value, for simplicity, the amount of the annual payment for interest and depreciation is found thus: If C be the cost of the unit; N the years of service life; r the rate of interest for fair return; and r' the rate to be used in amortizing the property; the total annual payment, P, by the public for fair return and depreciation is given by

$$P = C r + \frac{C r'}{(1 + r')^N - 1},$$

the second term being evaluated by logarithms or taken from amortization tables. It will perhaps be plain that this should be the payment for the first year, but for the second year the payment should include interest on the amortization annuity of the first year, if the public served is to pay the full depreciation as it accrues, and the return should be on the original cost reduced by the first annuity, just as in the straight-line method. For the third year, the cost, or value, should be reduced by the depreciation payments of the first two years, and the depreciation payment should include interest on the sum of the two preceding depreciation payments, and so on. Now it may be shown that if r' equals r, all these several annual total payments for interest and depreciation are identical in amount and equal to that first above written for the first year. If r' does not equal r, the total payments are not the same throughout the years. Table 2 will show the remaining value, depreciation accruing, and total payments on account of fair return and depreciation, when the amortization interest rate is assumed the same as the fair rate of return—5%, and when the latter is the larger—7 per cent.

This method of disposing of the payments of the public on account of fair return and depreciation was called, in the Progress Report, the equal-annual-payment method, because it seemed to make the total payments on account of operation, return, and depreciation more nearly equal from year to year than other methods that had been discussed. As it does not necessarily do this in all cases, it might better be distinguished from other methods by a more exact title. Under this method the total payment of the public served, for interest and depreciation, is divided into two parts, one the full annually accruing depreciation under the compound-interest theory, and the other, return on the depreciated cost of the unit. This is exactly analogous to the straight-line accounting method, the only difference being in the amount of the accruing depreciation. It is the complete and logical method of accounting for the payments of the public for interest and depreciation under the compound-interest theory of depreciation, and the method will be given the name of the theory and will be called the "compound-interest method", logically comparable with the use of the "straight-line method" under the "straight-line theory". Although the name "equal-annual-payment" has gotten into valuation and accounting literature, this literature is in a transition stage, and the Committee thinks there is good reason in the preceding argument for the new name.

2. *The Sinking-Fund Method.*—Sinking fund is a very old term and has long been connected with the plan of providing for the payment of a debt, which is to become due in the future, by setting aside and investing a properly determined annuity, such that, with accumula-

TABLE 2.—ILLUSTRATION OF COMPOUND-INTEREST (EQUAL-ANNUAL-PAYMENT) METHOD OF ACCOUNTING FOR DEPRECIATION.

Assumptions: Property having 20-year Life, Valued when New at $100. Computations of Depreciation Allowances Based on 5% Interest, Compounded Annually. Annual Return on Capital Invested, 5 and 7 per cent.

Age, in years.	Remaining value at end of year.	Depreciation during year = depreciation allowance.	Return on Remaining Value of Property at:		Combined Depreciation and Return	
			5%	7%	5%	7%
(1)	(2)	(3)	(4)	(5)	(6)	(7)
0	$100.00					
		$3.02	$5.00	$7.00	$8.02	$10.02
1	96.98					
		3.18	4.84	6.79	8.02	9.97
2	93.80					
		3.33	4.69	6.57	8.02	9.90
3	90.47					
		3.50	4.52	6.33	8.02	9.83
4	86.97					
		3.68	4.34	6.08	8.02	9.76
5	83.29					
		3.86	4.16	5.83	8.02	9.69
6	79.43					
		4.05	3.97	5.56	8.02	9.61
7	75.38					
		4.26	3.76	5.27	8.02	9.53
8	71.12					
		4.47	3.55	4.98	8.02	9.45
9	66.65					
		4.69	3.33	4.67	8.02	9.36
10	61.96					
		4.93	3.09	4.33	8.02	9.26
11	57.03					
		5.17	2.85	3.99	8.02	9.16
12	51.86					
		5.43	2.59	3.63	8.02	9.06
13	46.43					
		5.70	2.32	3.25	8.02	8.95
14	40.73					
		5.99	2.03	2.85	8.02	8.84
15	34.74					
		6.29	1.73	2.43	8.02	8.72
16	28.45					
		6.60	1.42	1.99	8.02	8.59
17	21.85					
		6.93	1.09	1.53	8.02	8.46
18	14.92					
		7.28	0.74	1.04	8.02	8.32
19	7.64					
		7.64	0.38	0.53	8.02	8.17
20	0.00					
		$100.00				

tions of interest, the amount of the funds in hand when the debt matures, will be equal to the amount of the debt. Only in comparatively recent years has the method been used for the amortization of wasting properties. It is not so well adapted to this purpose, as to

the amortization of a debt, particularly when the property is a public utility. The method contemplates the creation and maintenance of a fund which, considering the danger that it may be misapplied, is against good public policy. Moreover, when a property is growing it is good economy to use the annuities in extensions of the property; but there is danger, when this is done, that confusion in the accounting will result, and there is always danger that some persons may confuse annuities without their accretions, with the depreciation that the annuities plus their accumulations of interest are intended to cover. Under this method, the public served is credited with paying only the annuity toward depreciation, its payments on this account, therefore, being equal from year to year. The remainder of the total payment for interest and depreciation is treated as fair return computed on the undepreciated cost of the unit concerned. As this is also always the same, the total payments of the public for fair return and depreciation are always the same throughout the years, and the amount is that above written,

$$P = C\,r + \frac{C\,r'}{(1 + r')^N - 1}$$

If r' equals r, the total annual payments agree in amount with those of the compound-interest method, but, if the return rate is higher than the amortization rate, as has been usual in practice heretofore, the total annual payments by the sinking-fund method are larger in the later years than those of the compound-interest method as shown in Column (7) of Table 2, and thus the company owner is overpaid. It has already been argued that the same rate of return should be earned by all capital kept in or held for the property, and hence it should be true that amortization rates of interest should be the same as fair return rates, and they will be so considered in the remaining discussion. Thus, the total annual payments by both methods will be identical. As full payment for interest and depreciation is made under the compound-interest method and the same totals are paid under the sinking-fund method, full payment must be made under this method.

To defend crediting the public with only the annuities toward depreciation and full return on the undiminished cost of service units, one of two arguments is invoked:

1.—The annuities are paid to the company before it has occasion to use them to retire the units they are intended to cover; hence, the company owner can earn interest on them, and therefore they are discounted and considered parts of a fund held in trust by the company owner and invested for the purpose of earning that interest necessary to make it amount to the payment required of the public when the unit covered is retired. As the company may not earn distributable profits

on these annuities, it must be allowed its fair return on the undiminished cost of the units covered until such time as the fund matures, which in theory should be when the item is retired. If the fund is then immediately reinvested in the property, the cost value goes on as before; if, for any reason, it is withdrawn from the property, the cost value should be reduced accordingly.

2.—The public is assumed to make full payment on account of depreciation yearly as it accrues; but, because it makes these payments in advance of the time when they must be used to retire the unit they cover, the company owner will be able to use them to earn interest, and hence the public charges the company for the use of these payments assumed to be due only when the item is retired; that is, the public pays the present worth of payments assumed to be due on the retirement of the unit covered. But, again, the company owner must invest these annuities so that with their earnings they shall equal the cost of the unit covered when it is retired; they cannot be used to earn distributable profits, and, therefore, as before, the public should pay a fair return on the undiminished cost value of the units concerned until they are retired or the payments mature. Under this conception, it must be assumed, either that the last payment due is made first and discounted, or that the growth of depreciation is reversed, the larger annual growth being at the beginning and the smaller at the end of service life. The conception seems not to be defensible.

Comparisons.—The entries to be made in the accounting under the compound-interest and sinking-fund methods must of necessity be different. Under the compound-interest method, the book value of the service unit must be reduced from year to year in the amount of the full accruing depreciation by a credit to depreciation reserve; under the sinking-fund method, the public paying return on the undiminished cost, there should be no deduction from book value until the unit is retired or the sinking fund matures, which times are theoretically the same. Thus, the sinking-fund method becomes, so far as the property account is concerned, the same as the replacement method of maintaining property. Unfortunately, this has not been understood clearly, and the sinking-fund method of accounting has not proceeded under this theory; confusion has resulted, and, indeed, is likely to result, from any attempt to account for depreciation under this method.

The Entries Under the Compound-Interest Method are, and are explained, as follows: Income in the amount of the depreciation allowance is charged to operating expense to keep the income statement correct. Depreciation reserve is credited in the same amount to keep the property statement correct. We now have assets consisting of property depreciated by the depreciation reserve and cash or other assets equivalent to that allowance. The depreciated property will earn

fair return the next year, and the allowance also should earn fair return. It may be—and should be, if possible—at once re-invested in the property, but, however it is used, unless retained as working capital, cash will be credited and the particular asset purchased will be charged, thus making no change in the total assets. If the allowance is invested in the property, fair return presumably will be earned. If this is not immediately possible, so that the allowance must be held for a time until needed in the property, it should be invested in outside securities, and the deficiency of fair return, if any, should be charged next year in operating expense, and the excess above fair return, if any, should be credited to income, reducing the necessary payment of the public on account of depreciation. Only on such an assumption is it fair to use fair rate of return in computing annuities. If the company owner must take his chances of earning more or less than the fair rate of return on the annuities, then that rate should be used which experience shows to be probably obtainable. In the case of a reasonably growing property, investment in the property will usually be possible though perhaps not immediate; in the case of a stationary property, it will in general be impossible.

There is no ambiguity in the foregoing described method; no chance for confusion; the method is exactly analogous to that described under the straight-line theory of depreciation.

The Entries Under the Sinking-Fund Method should be, and are explained, as follows:

Operating income, in the amount of the annuity, is charged to operating expense in order to keep the operating income account correct. As fair return is based on book value, there must be no reduction in this below original value, except as units are retired, so there will be no credit to depreciation reserve, which will reduce book value, but to some other liability account as trust fund reserve. Among the assets, cash or other assets will be credited, and sinking fund charged with the amount of the depreciation annuity. The fund will be credited only as cash is expended for the replacement of, or in lieu of, units covered by the fund. The fund must be carried as an undistributable asset belonging to and going with the property, to offset the trust fund reserve. Accounting must go on within the fund; its cash must be invested and its income accounted for separately from the operating income. If its cash is reinvested in the property itself, purchasing new units and increasing the income producing but depreciating property, the earnings from such new units should be charged to the fund. These units being depreciating units must also earn depreciation annuities, which must in turn be invested and in effect a new sinking fund must be set up for each addition to depreciating property. It would be manifestly impossible to separate the earnings of the several units of a complex property, but the operating income

can be separated into two parts, respectively proportioned to the investment from the fund and that from other capital, and its due share charged to the fund. This will be but an approximation to the truth and again it must be remembered that the additions are of depreciating property. Moreover, in a valuation it will be impossible to distinguish between units purchased from the fund and those acquired otherwise. If the fund is invested outside the property, no difficulty arises in determining the income. Theoretically, if it is invested so that it earns less than the rate assumed in determining the annuities (which, as has been pointed out, should be the fair rate of return), the deficiency may be put in operating expense and so collected from the public; and, if it earns more than the fair rate of return, the excess should be credited to the public sinking-fund reserve to the relief of the public. However the fund is invested, it must be held to be a part of the undistributable property, an asset to be included in a valuation offsetting trust fund reserve.

The foregoing procedure is more complex than that involved in the compound-interest method, and the sinking-fund method has no advantage over that method in any way. It does not show directly in the property account what the accrued depreciation is at any time, as does the compound-interest method, but presents the fiction—possibly justified by the existence of the trust fund reserve—of an undepreciated property. It must be remembered that the company owner has two elements of value in his property—money and time—that is to say, cost and length of service life, both of which must be protected. It is not enough that when a property unit goes out of service there shall be a new unit of equal cost to replace it, but the new unit must have a service life equal to that of the retired unit, or, there must be more units of less life, or less units of more life. Under a strict application of the sinking-fund method, when the fund is invested in the property, the foregoing result is realized only if the funds be set up for each separate addition, purchased with fund money, based upon the cost and service life of the addition. The intricacies of this method when strictly followed, the confusion likely to result when the fund is invested in additions to the property, and the desirability of such (latter) form of investment, seem to make this method of accounting, for depreciation of a growing property, undesirable.

The sinking-fund methods in common use in the past have varied from the foregoing procedure. Either annuity or full amount of accruing depreciation has been charged to operating expense, and credited to reserve, thus reducing book value. When only the annuity has been charged and credited, the property account shows depreciation, but not enough, and explanation must be forthcoming to justify the accounts and the distribution of public payments. The accounts

do not tell the whole story, as in the compound-interest method. If the full accruing depreciation is charged and credited, no sinking fund is required, and no explanation can justify any other distribution of the public payments than that of the compound-interest method which this procedure then becomes.

The sinking-fund methods heretofore generally used are incomplete accounting methods, under the compound-interest theory, in that outside explanation is required to justify the accounts and the distribution of public payments for return and depreciation. Since, as has been said before, there is full and complete payment by the public for return and depreciation under the compound-interest method, and since, with equal rates for return and annuity, the payments are the same in total amount under the sinking-fund method, they must be complete under both methods, and it would appear that the sinking-fund method so widely used must have been the outgrowth of a failure to comprehend the problem completely. At any rate, it seems no longer desirable.

Comparison of Four Methods.—

(*a*)—Compared to Bond Payments.—The four methods of accounting for depreciation may be compared to four ways of making and paying bonds. Thus, the replacement method corresponds to a bond payable n years from date, with interest at the rate of r per cent. per annum until paid; the straight-line method corresponds to a set of n serial bonds of equal amounts, with interest at the rate of r per cent. per annum, giving diminishing annual payments; the compound-interest method corresponds to a set of n serial bonds of unequal amounts, respectively equivalent to the annuity accumulations of the several years that the bonds run, giving equal annual payments. The sinking-fund method corresponds to bonds payable n years after date, and requiring a trust fund to be accumulated with a bank or trust company to meet the payments when due, also giving equal annual payments.

(*b*)—On a Basis of Costs.—To compare the four methods thus far described on a basis of cost, it will be assumed that the property is made up of a single unit, costing $100, having no salvage value, and lasting 20 years—of course, a purely hypothetical case. If interest for all purposes is at 5%, the annual and total payments by the public to the owners will be as in Table 3.

In preparing Table 3, the return under the replacement and sinking-fund methods has been figured as 5% on the undiminished cost of the property unit, while under the straight-line and compound-interest methods it has been based on the depreciated value of the unit.

The headings in Columns 9 and 10, while representing what is frequently considered to be "depreciation" and "return", are not expressive of the facts. The figures in Column 9 represent the sinking-fund annuity for each year, which is only a part of the depreciation, as may

be seen by reference to the total at the foot of the column, which is only \$60.40 instead of \$100. The remainder of the depreciation is incorporated in the figures in the column headed "Return", where in each year it represents 5% on the difference between the undiminished cost of the unit and its depreciated value in that year. Of the \$100 represented by the total of this column, \$39.60 is "depreciation" and \$60.40 is "return".

TABLE 3.—Comparison of Combined Annual Depreciation and Return Upon a Property Unit of 20-Year Life, Under Different Methods of Providing for Depreciation. Assumed Rate 5 Per Cent.

Year (end of).	Replacement Method.	Straight Line Method.			Compound-Interest Method.			Sinking-Fund Method.		
	Return.	Depreciation.	Return.	Total.	Depreciation.	Return.	Total.	Depreciation.	Return.	Total.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
1	\$5.00	\$5 00	\$5.00	\$10.00	\$3.02	\$5.00	\$8.02	\$3.02	\$5.00	\$8.02
2	5.00	5.00	4.75	9.75	3.18	4.84	8.02	3.02	5.00	8.02
3	5.00	5.00	4.50	9.50	3.33	4.69	8.02	3.02	5.00	8.02
4	5.00	5.00	4.25	9 25	3.50	4.52	8.02	3.02	5.00	8.02
5	5.00	5.00	4.00	9.00	3.68	4.34	8.02	3.02	5.00	8.02
6	5.00	5.00	3.75	8.75	3.86	4.16	8.02	3.02	5.00	8.02
7	5.00	5.00	3.50	8.50	4.05	3.97	8.02	3.02	5.00	8.02
8	5 00	5.00	3.25	8.25	4.26	3.76	8.02	3.02	5.00	8.02
9	5.00	5.00	3.00	8.00	4.47	3.55	8.02	3.02	5.00	8.02
10	5.00	5.00	2.75	7.75	4.69	3.33	8.02	3.02	5.00	8.02
11	5.00	5.00	2.50	7.50	4.93	3.09	8.02	3.02	5.00	8.02
12	5.00	5.00	2.25	7.25	5.17	2.85	8.02	3.02	5.00	8.02
13	5.00	5.00	2.00	7.00	5.43	2 59	8.02	3.02	5.00	8.02
14	5.00	5.00	1.75	6.75	5.70	2.32	8.02	3.02	5.00	8.02
15	5 00	5.00	1.50	6.50	5.99	2.03	8.02	3.02	5.00	8.02
16	5.00	5.00	1.25	6.25	6.29	1.73	8.02	3.02	5.00	8.02
17	5.00	5.00	1.00	6.00	6.60	1.42	8.02	3.02	5.00	8.02
18	5.00	5.00	0.75	5.75	6.93	1.09	8.02	3.02	5.00	8.02
19	5.00	5.00	0.50	5.50	7.28	0.74	8.02	3.02	5.00	8.02
20	5.00	5.00	0.25	5.25	7.64	0.38	8.02	3.02	5.00	8.02
Depreciation	100.00									
Total.	\$200.00	\$100.00	\$52.50	\$152.50	\$100.00	\$60.40	\$160.40	\$60.40	\$100.00	\$160.40

Although the total payments by the public for return and depreciation appear from the footings, under the various headings, to be different under the different theories, this apparent variation is the result of ignoring interest on the payments or, in other words, the effect of time.

The real total cost of the unit in the 20 years, for interest and depreciation, is the accumulation of the annual allowances for these items at compound interest during the 20 years, and this is the same for the four methods and is equivalent to the sum to which

the cost of the unit would amount at compound interest in the life time of the unit, as will be shown.

Referring to Table 3: by the replacement method, the total return of \$5.00 each year may be considered as an annuity which at 5% in 20 years amounts to \$165.33, to which must be added \$100.00, the retiring payment, making \$265.33. By the straight-line method, the payment for the first year is \$10.00, which at compound interest for 19 years amounts to \$14.57; the second payment is \$9.75, which in 18 years amounts to \$13.92; and so on, the total for the 20 years summing \$265.33, as before. The payments by the two other methods are alike, \$8.02, and these, treated as annuities, also amount to \$265.33 in 20 years; but \$100.00, the first cost of the unit, if placed at compound interest at 5% for 20 years, also amounts to \$265.33. Thus is the statement of equal cost for the four methods and its equivalent shown for the particular case. It may be proved mathematically, as follows:

The sum to which any principal, P, will amount at r compound interest in n years is

$$S = P\,(1 + r)^n \quad \text{.......................}(3)$$

The annuity F that must be set aside each year at r compound interest in order to realize P dollars in n years is

$$F = \frac{P\,r}{(1 + r)^n - 1} \quad \text{.......................}(4)$$

and conversely the sum, P, to which an annual allowance at r compound interest will amount in n years is

$$P = \frac{F\,[(1 + r)^n - 1]}{r} \quad \text{...................}(5)$$

The total cost of any unit in n years, being the amount of the total allowances for interest and depreciation at compound interest, if n be taken as the life of a unit costing P dollars, then:

By the replacement method, the annual payments are Pr for interest, and, at the end of the nth year, a gross sum of P dollars to make good the worn-out item. In the n years, the total cost will be the sum of the annual allowances of Pr dollars at compound interest plus P dollars. Therefore, using Equation (5), in which F becomes Pr, we have

$$\text{Total cost} = \frac{P\,r\,[(1 + r)^n - 1]}{r} + P = P\,(1 + r)^n \text{....}(6)$$

which by Equation (3) is the amount of P at compound interest for n years.

By the straight-line method, the annual contributions are not equal. They are for each year $\frac{P}{n}$ for depreciation, and a varying amount

for interest, as the depreciation is deducted from the principal. The series of payments for interest may be expressed as follows:

First year............ $P\,r$

Second year........... $\left(P - \frac{P}{n}\right) r$

Third year............ $\left(P - \frac{2\,P}{n}\right) r$

etc.,

nth year.............. $\left(P - \frac{(n-1)\,P}{n}\right) r$

The total annual contribution then will be

First year........... $\frac{P}{n} + P\,r$

Second year .... $\frac{P}{n} + \left(P - \frac{P}{n}\right) r$

Third year............ $\frac{P}{n} + \left(P - \frac{2\,P}{n}\right) r$

etc.,

nth year.............. $\frac{P}{n} + \left(P - \frac{(n-1)\,P}{n}\right) r$

Substituting those separate sums in a series of equations based on Equation (3) making the exponent of the parenthesis $n - 1$ for the first equation, $n - 2$ for the second, and $n - n = 0$ for the last equation, there results:

For the first-year allowance.. $S = \left(\frac{P}{n} + Pr\right) (1 + r)^{n-1}$

For the second-year allowance. $S = \left[\frac{P}{n} + \left(P - \frac{P}{n}\right) r\right] (1 + r)^{n-2}$

For the third-year allowance. $S = \left[\frac{P}{n} + \left(P - \frac{2\,P}{n}\right) r\right] (1 + r)^{n-3}$

etc.,

For the nth-year allowance..... $S = \frac{P}{n} + \left(P - \frac{(n-1)\,P}{n}\right) r$

and the sum of these several sums is $P\,(1 + r)^n$, the same as given by Equation (3).

By the sinking-fund method, the annuity payment, Equation (4), is $\frac{Pr}{(1 + r)^n - 1}$, and the total annual payment is this plus interest, Pr.

Hence the total cost in n years is the accumulation of these two items or, substituting, $\frac{Pr}{(1+r)^n - 1} + Pr$ for the F of Equation (5),

$$\text{Total cost} = Pr \frac{\left[\frac{1}{(1+r)^n - 1} + 1\right]\left[(1+r)^n - 1\right]}{r} = P\,(1+r)^n \,.. (7)$$

or the same as by the replacement method, and as Equation (3).

Since the compound-interest sinking-fund method involves exactly the same annual contributions as the sinking-fund method, the total cost must be the same, or, $P\ (1+r)^n$.

For the particular example assumed, namely, a \$100.00 unit lasting 20 years, with interest at 5%, the total sacrifice for the 20 years, by any one of the methods, is

$$S = P\ (1+r)^n = \$100.00\ (1.05)^{20} = \$265.33.$$

(*c*)—With Respect to Legality and Safety.—The four methods showing identical costs, any one of them seeming to be most convenient may be chosen for a particular property or for a part of a property, provided only that it is legal, safe and fair, but the sinking-fund method, being incomplete within itself, is not recommended. The replacement method is open to the danger that a Court, valuing a property at any time, will charge against it whatever depreciation may be found, holding that depreciation of physical property is always loss of value of investment, and that, under the Knoxville decision, it must be deducted, whether or not, under accounting methods theretofore used, the depreciation had been collected from the public. Thus, the property would lose the accrued obligation of the public to pay for depreciation, which obligation must be considered an asset of the property in an equitable treatment of property maintained under the replacement method of accounting. When the method is ordered or authorized by a public regulating body, as has been done in the past by the Interstate Commerce Commission with respect to all railroad property, and is still approved for most classes of such property, it should be considered to be legal and should be safe, but not always has it been safe.

The straight-line and compound-interest methods plainly are safe, as they return the full amount of the depreciation presumably as it accrues.

The sinking-fund method perhaps requires interpretation to make clear when it is safe, as the public apparently does not return the full amount of the depreciation to the owner, and unless fully understood and properly applied by regulating or valuing bodies, it is not safe. Since the total annual payments for interest and depreciation by this method are exactly the same as by the compound-interest method, it must follow that if full payment is made in one case it is also made

in the other, and that it is merely the bookkeeping distribution of these payments which makes it appear that full payment is made in one case and not in the other. Under the sinking-fund method of accounting, the annuity assumed to be paid by the public, together with the interest on the accumulated allowances, must be charged each year to the fund held in trust for the property. The fund must be treated as a trust fund belonging to the property, or due from the public, and equivalent to physical property of equal value.

If for the purpose of public purchase or capitalization a valuation is made at any time of a property maintained under this method, depreciation will exist in amount equivalent to the accumulation of depreciation annuities and interest, if the various original estimates on which the annuities were figured have agreed with the facts as they have developed in the life of the property. To the depreciated value found will be added the accumulated allowances not invested in the property but treated as an asset due from the public and neither the company owner nor the public will lose anything, since 100% of original value will be found and the accounting may go on as before. If part of the fund is invested in additions and betterments, it will be difficult, if not impossible, to separate these from the original property, and they will be included ordinarily in the valuation; but the fund accounts should show what sums have been thus invested and what amounts remain in the fund as other assets. Only the portion of the fund not invested in the property can be added to the depreciated value. Again 100% of original value will be found to result, and purchase price will be so fixed, or the accounting may proceed as theretofore. The sinking-fund method, being likely to cause confusion and possible injustice, should not be used in depreciation accounting, but, if used, difficulties may be somewhat avoided if the fund is kept invested in assets wholly distinct from the property.

If a valuation is for the determination of fair return for the future, either of two courses is open: (1) The property may be listed at full value for the determination of interest, and full value and total service life for the determination of depreciation annuity; or, (2) The property may be listed at depreciated value for the determination of interest, and depreciated value and remaining service life for depreciation annuity. Either method is equitable, and both give the same total annual allowance. Thus, referring to Table 2, if a 20-year item costing $100.00 new has been in service 15 years, and interest is figured at 5%, the theoretical remaining value, under the compound-interest theory, is $34.74. The interest for the succeeding year is $1.73, and the depreciation annuity to retire the item in 5 years is $6.29, or a total of $8.02, which is just what is required to cover interest and annuity for the item considered new. A danger here—shown by experience to be real—is that the property will be listed at depreciated value for

interest and full value and total service life for depreciation annuity.

Rate on Depreciation Allowances.—As having some bearing on accounting methods, the disposition of allowances, and the rate to be used for these allowances, the Committee desires to emphasize again the fact that the entire reasonable sum devoted to public service is entitled to a uniform fair return. While thus devoted, and while, as a matter of convenience or to conform to law, allowances for depreciation may be returned to the company owner approximately as the depreciation goes on, thus theoretically reducing the capital in the service, yet the obligation of the owner to keep the investment in the property intact, makes it improper for him to consider these allowances other than as a part of the property not to be distributed as income, or returned to his pocket, without corresponding reduction of capital, if not needed for the maintenance of the property. Therefore, he is entitled to a full fair return on the undiminished investment so long as its value is properly maintained in accordance with law. Hence the allowances returned to the investor to cover accruing depreciations should earn the same fair return as the value remaining in the property. To accomplish this these allowances are best invested in the property, but, when this is not possible, the amounts not thus invested should be placed in a fund sacred to the property, and the earnings of this fund should be accounted for—if less than a fair rate of return, the deficiency should be charged in operating expense; if more, the excess should be credited to income. Thus only will the public pay its just payment and the property receive its fair return and no more. This may be difficult or impracticable of exact accomplishment.

This means that interest on depreciation allowances should be at the same rate as the fair rate of return, and that this is the rate to use in computing annuities, and allowances under the compound-interest theory.

Accounting Depreciation, the Result.—As a result of approved accounting methods that include a reserve account and that have been used from the beginning, there will appear on the books at any given time a sum that may be called accounting depreciation. For those items maintained by the replacement method and for which reserves are not set up the sum will be zero, there is no accounting depreciation under this method. The Interstate Commerce Commission has recommended that reserves be established for all properties, and there is much to be said in favor of this recommendation. If a reserve account is set up, the balance in that account shows the amount of accounting depreciation for property in use.

If no reserve account is set up, there is no account that will show at once the amount of the accounting depreciation. The way to determine it is to compare the presently carried property statement with the original costs of the property in use, if these can be found;

the difference is the accounting depreciation for the methods of bookkeeping in use. Under the sinking-fund method, there should be no reserve set up against the property, but the balance in the trust fund reserve, which should in this case equal the fund, is the accounting depreciation.

Unless reserves are set up for all property, as has been recommended by the Interstate Commerce Commission, or a full depreciation fund is maintained, accounting depreciation can never agree with the depreciation present at any given time, but it should agree substantially with it for those units or items which are maintained from the beginning under depreciation allowance methods, if the estimates of service life on which the allowances have been based have been correct, and the property has worn at the rate assumed by the particular allowance method adopted.

The straight-line method will show at any time a larger accounting depreciation than either of the compound-interest methods.

Summary.—None of the allowance methods works out in practice exactly as indicated in the tables. Accidents, and errors of judgment in prophetic estimates of service life, may cause sums received for depreciation to be excessive or deficient, but, in the accounting of a continuing property, these differences can be adjusted from time to time.

In the opinion of the Committee, the several methods described are respectively more particularly applicable as follows:

The replacement method is applicable to those short-lived properties or parts of properties made up of a large number of items, the replacement or retirement of which proceeds after a time with fair regularity and causes no troublesome variations in return or service rates. Railroad ties are an example. Rails, when a part of a very large property, and machines where very many are owned and used, may also be handled by the replacement method. Although applicable to all such properties or parts of properties, the replacement method is at present undesirable because it may result in loss to the company owner in the case of a valuation, determined under an interpretation of the Knoxville decision, which holds that all loss of service life of physical items, except such as is made good by current repairs, is loss of value of investment, and that obligation of the public to pay can never be accepted as an asset to offset accrued depreciation.

The straight-line method of accounting applies to any property units having more than a year of service life, which are assumed to depreciate according to the straight-line theory. The compound-interest theory applies similarly to property units assumed to depreciate according to the compound-interest theory. Under either method it may be necessary to maintain a fund not invested in the property itself, as when the property is stationary or consists of only a very few large

units of long life. For such properties the sinking-fund method of accounting could be adopted, if the compound-interest theory is held to apply, provided it is fully understood and correctly applied, but it is not recommended.

The great discrepancy in the growth of depreciation of long-lived units under the straight-line and compound-interest theories should be carefully noted when determining which theory to use. For short-lived items there is not much difference, and in some cases the straight-line theory may result in more uniform annual payments than the compound-interest theory; but, as already pointed out, there is a very great difference in the results of the two theories when applied to long-lived units. For such units, the Committee believes that the compound-interest theory is more nearly in accord with the truth as expressed by the unit-cost theory, which is thought to give results most closely corresponding to actual depreciation, and here the compound-interest theory would seem best to apply.

The extent of the difference in the amount of depreciation under the straight-line and compound-interest theories, for property units having various lengths of service life, is shown in Table 4. It is to be noted that the first column shows the percentage of the total service life which has expired, and consequently the percentage of existing depreciation computed under the straight-line theory. The remaining columns show the corresponding percentage of depreciation under the compound-interest theory based on a 5% interest rate compounded annually. For example, when 20% of the life of a property unit has expired, the depreciation by the straight-line theory would be 20%, regardless of the length of life of the unit, but by the compound-interest theory the depreciation would range from 16.3% for a unit having a life of 10 years to 1.3% for a unit having a life of 100 years.

TABLE 4.

Percentage of total life which has expired = percentage of depreciation by straight-line theory.	Percentage of Depreciation Under Compound-Interest Theory, Corresponding to Percentage of Loss of Service Life Given in First Column.				
	10-year unit.	25-year unit.	50-year unit.	75-year unit.	100-year unit.
10	8.0	5.5	2.6	1.2	0.5
20	16.3	11.6	6.0	2.9	1.5
30	25.1	18.6	10.3	5.3	2.5
50	43.9	35.3	22.8	13.8	8.0
70	64.7	56.6	43.1	31.6	22.5
90	87.7	83.8	76.3	68.6	61.1

This report is particularly concerned with depreciation accounting as it relates to valuation, and the determination of the depreciation of valuation. It would seem to be fair in any given case to give

the method of accounting used by the utility in setting up depreciation allowances its proper effect in determining deductible depreciation or the depreciation of valuation. The foregoing discussion of the several more common methods is given in order that the proper effect of each may be better understood by the valuing engineer.

The Depreciation of Valuation, or Fair Depreciation.

Cost of Decretion.—Finding the cost of decretion is a step in the determination of depreciation, but the result is not necessarily depreciation of valuation. By cost of decretion is meant the loss of service life of an item converted into loss of value. This produces what is sometimes called depreciation and what is depreciation for the particular item. As it may or may not be a quantity to deduct from cost or other base for value when finding value or "fair value", it is not called depreciation here, but cost of decretion, simply to avoid confusion likely to result from the use of the word depreciation in more than one sense.

The first step in estimating the cost of decretion is to make the necessary examination of the property unit by unit. This examination should include an investigation of every element that has any bearing on the future and past service of each item and the character of its maintenance. From the investigation an estimate will be made of the remaining service life of each unit under the method of maintenance being followed; its past service life will be known; from these its total estimated service life, which may or may not agree with assumptions made for past accounting purposes, is found. Examination should show also the efficiency of operation of each unit.

To estimate the fraction of service life consumed requires a knowledge of past service and an estimate of future service life. There are two questions of importance to be discussed in this connection.

1.—Treatment of Inadequacy and Obsolescence.—Experience furnishes a guide in the making of reasonable estimates of service life for those property units devoted to well-known operations, unlikely to be superseded by newly invented units to perform the same service, or to be rendered obsolete or inadequate by the changing requirements of a shifting population, or of commercial methods, or the changing habits and demands of the community. It is very difficult, in some cases, however, to make such estimates for property units which are likely to go out of service for one reason or another before they are worn out.

Nevertheless, it is recognized to be good business policy to make the best estimate possible in the light of such experience as may be available, and to fix a periodic allowance for depreciation reserve accordingly. Indeed, it is prescribed by the Interstate Commerce Commissions and many State Commissions, that the estimated effect

of inadequacy and obsolescence shall be included in the depreciation periodically credited to reserve by common carriers. Many State commissions make the requirement that these causes shall be included, not only in fixing the depreciation credited to reserve, but in fixing the amount of depreciation to be deducted in determining the "fair value" of a property.

Although the matter has not been definitely passed upon by the United States Supreme Court, some Federal and higher State Courts have recognized the propriety of including inadequacy and obsolescence as factors in the determination of depreciation.

The estimation of inadequacy and obsolescence is of necessity somewhat more speculative in character than the estimation of the results of wear, tear, and decay, but there is greater or less speculation in all estimates of future service life of physical property, and it would seem to be inconsistent to consider functional depreciation in estimating depreciation allowances to be charged to operating expense, and then to ignore it in a valuation.

The Illinois Public Service Commission, in the case of City of Springfield *v.* Springfield Gas and Electric Company (March 9th, 1916), in the course of a long discussion and review of the opinions of the Courts on this subject, says:

"Depreciation, accordingly, may be divided into two classes: physical, due to wear and tear; and functional, due to inadequacy and obsolescence which require replacement of equipment before it actually is worn out.

"It is the opinion of this Commission that the weight of authority compels a reasonable deduction from cost new for accrued depreciation —both physical and functional— * * *."

"In view of all facts in this case, the Commission finds that it is but reasonable, proper, and equitable to make deductions from cost new to cover accrued depreciation, both physical and functional, and that it is proper to treat depreciation consistently in all its features. Nothing in the record, and no theoretical consideration presented in this matter, are of sufficient weight to cause the Commission to depart from this reasonable and thoroughly consistent treatment of depreciation, which not only possesses judicial sanction but also is sound in both economic theory and business policy."

The California Railroad Commission, in the case of the Central Pacific Railway Company, decided December 8th, 1915, gives the following definitions which refer to functional depreciation:

"Physical depreciation is caused by the action of the elements and the wear to which a facility is subjected; functional depreciation is caused by the inadequacy or obsolescence of the facility, due to developments which have made it incompetent to perform its function properly or economically.

"Reproduction cost of a railroad less depreciation, in a valuation for general purposes, is the reproduction cost less the diminution in

the value of the physical elements of the property, due to use, age, *obsolescence, inadequacy,* or other causes, plus the increase in value of physical elements due to age or other causes." (Italics ours.)

In the case of the Chesapeake and Potomac Telephone Company of Baltimore City, decided March 8th, 1916, the Maryland Public Service Commission made the following statement:

"Any theory for ascertaining existing depreciation in the plant of a public utility which confines such depreciation solely to the actual, visible, physical, demonstrable deterioration which can be seen by the human eye and measured by the human hand, must of necessity ignore that other species of deterioration which the experience of the past has demonstrated beyond peradventure exists in the property of every telephone company, although it can not always be seen by the human eye or measured by the human hand.

"We refer to that tendency upon the part of all such property to become inadequate or obsolete with the lapse of time. We find it in the case of practically every building which this company owns. Ample, adequate to-day, they may become entirely inadequate to-morrow."

The Colorado Public Utilities Commission, in the case of the Colorado Springs Light, Heat and Power Company, decided March 1st, 1916, made the following statement:

"This Commission is familiar with the decision of the Idaho Supreme Court in Murray *v.* Public Utilities Commission, 150 Pac., 47, and with the theory there announced that there should be no theoretical accrued depreciation deducted from the reproduction cost of the physical property, but the court there states that actual depreciation should be deducted. Just what method an electrical engineer may use in arriving at the actual depreciated value of an electric property without considering theoretical depreciation is somewhat beyond our scope of vision."

A limited search of the practice of public service commissions indicated that inadequacy and obsolescence were included either in ascertaining the amount of depreciation to be included in earnings, or to be deducted from cost to obtain "fair value", by the commissions of the following states: Arizona, California, Colorado, Illinois, Maryland, Massachusetts, New York, Oregon, South Dakota, Wisconsin.

The Board of Public Utility Commissioners of New Jersey, in a decision concerning the rates of the Public Service Gas Company (1 N. J. Bd. P. U. C. 433, December 26th, 1912), distinguished between what is called, in its decision, theoretical depreciation, which must be sufficient to take care of obsolescence and that depreciation which can be determined by observation and inspection, and took the view that, in the future, allowance should be made for depreciation on the theoretical basis, but that as applied to an existing property, where it appears that the depreciation, credited to depreciation reserve in the past,

has not included the effects of inadequacy and obsolescence and thus been collected from the people, nothing should be held against the property for accrued depreciation due to these causes. The decision includes this statement:

"We believe that from this time forth allowance for depreciation should be made where possible, on the theoretical basis, but where depreciation has been charged off, the amount charged off appears to have been not theoretical depreciation, but merely amounts which would measure depreciation ascertained by inspection. We, therefore, conclude that we are on certain ground when the allowance for depreciation which is deducted from the cost to reproduce the property new is the amount representing the wear and tear and aging, and when we do not attempt to estimate the greater amount which would allow for obsolescence and inadequacy."

Although the matter of the inclusion of obsolescence and inadequacy has not been passed upon definitely by the United States Supreme Court, it is possible to infer from the language used in the Knoxville case and in the Minnesota rate case that the Court had in mind as a part of depreciation that due to inadequacy and obsolescence. In the Minnesota rate case the following language is used:

"As the Master said, everything on and above the roadbed depreciates from wear and weather stress. The life of a tie is from 8 to 10 years only. Structures become antiquated, inadequate and more or less dilapidated, * * * cars, locomotives and equipment, as time goes on, are worn out or discarded for newer types."

The use of the terms "become antiquated", "inadequate", "are discarded for newer types" clearly indicates that the master had in view depreciation from obsolescence and inadequacy, and although the Court quotes his statement it makes no unfavorable comment upon these features.

The decision in the Knoxville case contains the following language:

"But the reservoirs, the mains, the service pipes, structures upon real estate, standpipes, pumps, boilers, meters, tools, and appliances of every kind begin to depreciate with more or less rapidity from the moment of their first use."

Since about the only way that reservoirs can depreciate is through obsolescence, their inclusion in the foregoing statement, if not accidental, must have been based on a consideration of obsolescence.

A case in the Federal Court, recognizing the inclusion of functional depreciation in determining the sum to be deducted from reproduction cost, is that of the Des Moines Water Co. *v.* City of Des Moines (192 Fed., 193, 197, Sept. 16, 1911), in which it is stated:

"* * * the question is, What would it cost to-day to reproduce the plant? and from which, to get at the value of the present plant,

there would be deducted the value of depreciation, either by functional or physical depreciation."

In the Kings County Lighting Company case, the New York Public Service Commission for the First District included the effect of inadequacy and obsolescence in the determination of the amount to be deducted from cost for depreciation. When this case was appealed to the Appellate Division of the Supreme Court, that Court decided (People *ex rel.* Kings County Lighting Co. *v.* Willcox, 156 N. Y., App. Div., 603, May 9, 1913) to confirm the action of the Commission, but did not discuss obsolescence or inadequacy.

While most of the opinions of public service commissions and Courts in recent years have favored the inclusion of inadequacy and obsolescence, it is by no means uncommon to find in the opinions of masters and minor Courts, and sometimes of higher Courts, the expression of the view that all depreciation based on the life of a property unit should be excluded, and this would cover the exclusion of inadequacy and obsolescence. The basis in such opinions appears to be largely that, where the service is maintained at 100% efficiency, there is no depreciation. A recent opinion of this kind was that of the Supreme Court of Idaho (Murray *v.* Public Utilities Commission of Idaho, 150 Pac. R., 47, July 1, 1915):

"This Court is of the opinion that the rule of cost of reproduction less depreciation, adopted by the commission, is the correct general rule or principle to be applied in this class of cases. However, we believe that in ascertaining values in this way the worth of a new plant of equal capacity, efficiency, and durability, with proper discount for defects in the old, and the *actual depreciation for use,* should be the measure of value, rather than the cost of exact duplication.

"So far as the question of depreciation is concerned, we think deduction should be made only for *actual, tangible depreciation,* and not for theoretical depreciation, sometimes called 'accrued depreciation'. In other words, if it be demonstrated that the plant is in *good operating condition, and giving as good service as a new plant,* then the question of depreciation may be entirely disregarded." (Italics ours.)

Whitten, Vol. II., page 1150, gives a part of the decision of the Railway and Canal Commission of Great Britain concerning the value of the property of the National Telephone Company and its transfer to the Postmaster-General at the expiration of the Company's license on December 31st, 1911. (16 A. T. & T. Co. Com. L., 491, Jan. 13, 1913.) Whitten makes the following statement:

"Under the purchase agreement between the parties dated August 8, 1905, the purchase price was to be based substantially upon the reproduction cost of the physical property less depreciation.

"In this case the Postmaster-General contended that in computing the life of the plant for the purpose of estimating accrued depreciation,

the life period should be reduced on account of a probable shorter 'effective life' due to inadequacy, obsolescence, or other factors requiring supersession of a particular unit before it has been worn out. The greater stress was laid upon probable supersession through inadequacy due to the probable growth of the telephone business. The court held, however, that to give weight to these considerations involved a confusion of thought and that the possible and even probable growth of the Postmaster-General's telephone business had no bearing upon the present value of the Company's plant. The court, however, attempted to make due allowance for all functional depreciation actually existing in the plant at the time of the valuation."

The trend of opinion at the present time seems to be in favor of including inadequacy and obsolescence as factors in determining depreciation, both as to the sum to be deducted from cost to obtain cost less depreciation and as to the sum to be included in earnings. Until there shall have been authoritative court decisions in this country covering this matter, the estimator should proceed with caution, giving the property the benefit of any doubt, lest by mental speculation he destroy actual, existing value. Where the financial history of the property shows that the charges for depreciation have not included obsolescence and inadequacy, equity seems to require that they should not be included when determining the reproduction cost less depreciation of the property.

Under existing circumstances it is well to segregate the depreciation due to inadequacy and obsolescence from that due to other causes, that the propriety and effect of its inclusion may be weighed by the Court.

2.—Mortality Tables to be Used with Care.—It has been suggested already that remaining service life is determined as the result of examination and investigation; that depreciation is due to several causes, one or more of which may be chiefly responsible for loss of value in any particular case. The purpose of this paragraph is to emphasize this point and to suggest that ordinary mortality tables for physical properties are not to be carelessly used in this connection. The determination must be based on an investigation which includes not only age but character of past, present, and probable future service, character of past, present, and probable future maintenance, possible apparent or probable approaching inadequacy or obsolescence; and often the accounts must be examined to find the amount of money spent in repairs and general upkeep, and the regularity of the expenditure. Not only these but experience with other like properties under similar conditions should be considered, and sometimes properly prepared mortality tables giving estimated service life may be useful.

As has been suggested, many properties under proper maintenance will last forever, so far as human intellect can comprehend the meaning of that term.

That this is practically true, present existence of the following named structures seems to prove:

Main stone sewer, Rome	Built	600 B. C.
Arch bridge, San Angelo, Rome	"	200 A. D.
Several stone bridges at Nuremburg	"	1486-1728
Wooden bridge (Kapollsbrücke)	"	1333
Iron suspension bridge, Nuremburg	"	1824
Westminster Abbey, London, old portion stone	Built	13th Century
Ratfield House, England (Marquis of Salisbury)	"	1611—Stone.
Saint Lawrence Church (Nuremburg)	"	1477— "
South Church, Boston	"	1750—Brick.
Church, Alexandria, Va	"	1784— "
Howland House, Plymouth, Mass	"	1660—Frame.
Windmill, Nantucket, wood and shingles	"	1746— "
Washington's home, Mt. Vernon, Va	"	1784— "
Hobson's House, Montgomery, Ala	"	1815— "

On the other hand, apparently permanent structures have but a short life; what were new high buildings only a few years ago are already destroyed to make way for yet higher buildings. This means inadequacy and obsolescence. It shows that mortality tables based on the older structures are not applicable to the modern structures, and, based on averages, they would be likely to be far from the truth in any particular case.

At a recent meeting of railroad equipment officers from all sections of the United States it was determined from railroad records that:

"Obsolescence and inadequacy have been the cause of retiring practically all equipment in this country, and wear and age have not, except in very few cases, been the cause of retirement. There is, therefore, little data on which to base life tables, and as wear and age have not been the cause of retirement, experience is lacking which would permit the preparation of such life tables."

Although data may be lacking on which to base estimates of future loss of service life due to age and use, it would seem that, with all the data available with respect to inadequacy and obsolescence, there might be sufficient to estimate in a general way what the service life of railroad equipment is under varying conditions of service. Indeed, some such estimate must be made for any given road, in order to fix reasonable depreciation allowances for equipment as required by the regulating body. An estimate prepared with care for any given unit from a large number of data covering the service life of similar units would certainly be more trustworthy than one based solely on an examination of the particular unit. Tables showing the lives of certain units will be found in Appendix II.

Depreciation of Overhead General Expense.—Shall depreciation be estimated on overhead and general expense? The Committee believes

that the answer depends on the character of those expenses, and divides them into two classes: (1) Those which, like promotion expense, preliminary and location surveys, legal and other expenses, connected with the creation of the property, cannot be segregated into parts assignable to particular units, but apply to the property as a whole; (2) Those which would be incurred were the units to be reproduced, not as a part of a general reproduction, but for the maintenance of the property.

Expenses of the second class may be included sometimes in unit prices, but are not always entirely separable. Expenses of the first class cannot be thus included. The test as to whether or not a particular item of overhead shall be depreciated is: Will it be incurred in replacing units that are retired. If so, it is part of the cost of those items the service life of which is being consumed, and hence will be a part of the sum to be depreciated with the loss of service life of those items. If not, it is a part of the ever continuing property, and can suffer no depreciation except as the exchange value of the whole property may be lowered, in which case everything that went to make it loses value.

The Committee is of the opinion that all overhead charges which may be included in the unit prices of particular units, or which are specific charges against particular structures, should be depreciated, if the particular units or structures are to be depreciated, and as a part of the cost of those units or structures; that all overhead charges which would be incurred in replacement of units but which may not be easily separable in a reproduction cost estimate, should be depreciated by the average depreciation assigned to the units to which they belong; that overhead charges appertaining to the property as a whole and not to be reincurred in the replacement of units should not be depreciated at all, if the property is a continuing one.

Depreciation of Valuation Affected by Accounting Methods.—Decretion or loss in service life being always present in any going property, the cost of decretion is always present. Decretion is a fact, and is independent of methods of accounting, or character of regulation, but is much dependent on character of maintenance. In determining it, one is not helped in any way by reference to the accounting methods. He must examine the property units, estimate their remaining service lives, know their elapsed service lives, the character of their past service and maintenance, and the prophecy as to future service and maintenance. To estimate the cost of decretion one must know, also, the costs or estimated reproduction costs of the property units, but the amount of the estimate and whether or not it shall be treated as depreciation of valuation may be, and very probably will be, dependent, at least in part, on methods of accounting for depreciation

that have prevailed. Whether or not it will thus depend may also depend again on the character of public regulation.

(*a*)—Replacement Method.—If by order or sanction of a regulating body, or by long continued proper custom under no regulation, a property has been maintained in normal working condition, necessarily less than new in some or all of its parts, by the replacement method, and at any given date is being valued for any public purpose and at that date shows normal condition, all its several parts being in as good condition as could be expected, the accounts showing that always those amounts have been expended in renewals that were necessary to keep the property in normal working condition, and the fact appearing that no expenditure reasonably to be expected could put the property in better than the normal condition in which it is found, and that no unusually large expenditure is presently to be necessary for this purpose, then, in spite of the fact that there is an existing decretion in its several parts, there should be found no depreciation of valuation. Under the method of accounting, the public has not paid, and could not pay, for the accrued depreciation, and under this condition its accrued obligation to pay should be considered an asset of the company owner.

If parts of the property are maintained under the replacement method and part by some proper allowance method, except as noted below, then depreciation of valuation should be found with respect to those parts maintained under the allowance method, but this depreciation of specific physical units will be made good in whole or in part by existing funds or property purchased with allowances, either or both of which will be included in the valuation as they are found.

Railroads are properties of the class just considered. Their owners have long maintained the greater part of their perishable properties by the replacement method, and, except for a comparatively recent requirement of allowances or reserves for equipment, this method has been sanctioned by the Interstate Commerce Commission. Therefore, for such properties as are found in normal condition, as suggested above, there will be no depreciation of valuation for those items maintained by the replacement method. If these items are found below normal working condition, there will be depreciation of valuation, sometimes called deferred maintenance, and it will be measured by the sum necessary to bring the items to normal working condition—not new, the initial decretion necessarily present in such items in normal working condition being ignored, but upon restoration to normal working condition, the integrity of the investment should be considered to be renewed.

If in the judgment of the valuing engineer, the replacement method may not be used with propriety for a given property, either because not in accordance with law, or because the method is not adapted to the property, then whether or not the property has been maintained in the

past under this method the valuing engineer should estimate depreciation in the amount of the cost of the decretion he finds. There can be no certainty that the property will be properly maintained in the future.

When a comparatively new property, other than a railroad, is to be valued, and it has not been under any regulation that has affected its accounting methods, the law as laid down in the Knoxville decision would seem to make it necessary to find depreciation of valuation in amount equal to the cost of decretion found for all items, whether or not maintained by the replacement method. The Committee, however, believes that this may work hardship and injustice in some instances, and suggests that in such cases the facts be reported with such recommendations as to equity, as may seem fair to the engineer.

The public utility is entitled to see that from earnings the value of the property invested "is kept unimpaired" and that "before coming to the question of profit at all, the company is entitled to earn a sufficient sum annually to provide, not only for current repairs, but for making good the depreciation and replacing the parts of the property when they come to the end of their life". This is a reasonable right, the existence of which permits of renewals of parts of a property, that can be called current repairs, under the replacement method.

(*b*)—Allowance Methods.—If either the straight-line or sinking-fund theory has been used in computing depreciation and the method of accounting for it has been prescribed by a regulating body or voluntarily followed by a company owner from the beginning, the same theory, so far as it applies to the property in question, should be used for estimating the cost of decretion, and the entire cost so found lessened by any accumulated depreciation funds will appear as depreciation of valuation, unless the sinking-fund method of accounting has been used. In the latter case, if the valuation has to do with the reasonableness of the return and the accounting is to go on as before, apparently-existing depreciation would not be *depreciation of valuation,* and therefore would not be deductable; but if the valuation has to do with condemnation or purchase, then, as in other cases, the apparently existing depreciation is depreciation of valuation, and the owner should receive the depreciated value of the physical property and the existing fund.

As has been said, the unit-cost method of estimating depreciation can hardly be used with convenience as an accounting method. When there has been no regular depreciation accounting method followed, the unit cost method for estimating depreciation at any given time may be used with fairness.

The Committee has advised that the proper interest rate to be used in computing depreciation annuities is the same as the fair rate of return. This advice pertains to present and future accounting.

If, however, an old property, that has been properly maintained under the sinking-fund theory, is to be valued, that rate of interest should be used in computing the growth of theoretical depreciation that has actually been realized and has produced the existing depreciation fund or reserve. If there has been no depreciation accounting and it is desired to estimate the accrued depreciation under the sinking-fund theory, the engineer may choose the interest rate, but, inasmuch as new accounting to be installed after the valuation or rates to be based on the valuation should include, in accordance with the Committee's advice, an interest rate for depreciation equivalent to the fair return rate on capital, it is suggested that this same rate be used in computing the accrued depreciation.

Effect of Investing Allowances in the Property.—Under the straight-line or compound-interest method of accounting it is contemplated that, so far as possible, the depreciation allowances shall be invested in additions or betterments to the property. If such contributions of the public toward depreciation of existing property are invested in betterments and additions, then there must be depreciation of valuation to whatever extent cost of decretion is found, because in the inventory the betterments and additions made with the depreciation allowances will be listed as part of the property to be valued just as are the original items, the depreciation allowances for which were used to provide the betterments or additions. There will be no offsetting funds, but there will be property contributed by the public which cannot be capitalized and for which credit can be given to the public only by deducting an equivalent depreciation.

If, at the time of any valuation, not all the contributions of the public toward depreciation have been re-invested in the property, depreciation of valuation should still be found in the amount of the estimated cost of decretion of the physical property, but this will be offset to such extent as other assets, such as cash or outside securities, are in hand representing the portion of allowances, not re-invested in the property, but held for this purpose, and which, therefore, should be inventoried and included in the valuation.

Effect of Regulation on Depreciation of Valuation.—Regulation which determines the method of accounting will in part determine the amount of depreciation of valuation when finding "fair value", because it determines the method by which the public shall pay for the loss of service life.

It has been said by the Courts that it is not possible to go into the unregulated past to find losses or excessive profits, but if there has been regulation determining the method of accounting for depreciation from the beginning, or for a long time, and this regulation has fixed the sums to be included in the earnings for depreciation, it should be permissible to inquire into the adequacy of these sums. It seems

clear that in this respect it is proper to go back into the past and inquire to what extent the public has compensated for the loss of value due to loss of service life. If the regulating body has prescribed the replacement method for the whole period that units have been in existence, then, although depreciation may exist, it is not depreciation of valuation, because, under the method of accounting, the public has not paid, and could not pay, for the accruing depreciation, and is still under obligation to pay for it.

Methods of accounting in force at the present time which make proper provision for the accruing depreciation should not have full weight, if, in previous years during the life of the property units, other methods were in use which did not make proper provision for such depreciation. The amount of depreciation of valuation in such cases should be equivalent to the accumulated contributions of the public for depreciation allowances under the various methods of accounting which have affected the property unit from time to time. The public is still under obligation to make good that part of the loss of service life not yet paid for, and this obligation should be considered to be as much the property of the company usable to offset accrued depreciation as renewal funds or property actually in existence.

Whether or not this reasoning will stand in any case is for the Court to determine. Valuing engineers and accountants should report what they find as to the actual cost of decretion, and the sums which have been received to offset such cost, under the methods prescribed by the regulating body from time to time. They may give their opinions as to the amount of depreciation that should be deducted from cost to find cost less depreciation as an element in the quantity known as "fair value".

If regulation has not fixed accounting methods, but has limited the earnings, it should be permissible to inquire whether the limited earnings have been sufficient to pay operating expense, depreciation, and fair return. If so, depreciation found should be considered depreciation of valuation to the extent warranted by the accounting methods lawfully or properly followed; if not, a question arises. It is remembered that the duty of the company owner is first to maintain the property "before coming to the question of profit at all", and that it is the duty of the regulating body to see that rates are such as to permit the company owner to earn operating expense, depreciation, and fair return. If the regulating body has made sufficient earnings impossible, is it still the duty of the company owner to maintain the property before paying fair return to its security holders? If it is, depreciation of valuation should be found in the amount of the total cost of decretion or so far as warranted by the accounting methods followed. If not, depreciation found should not be considered depreciation of valuation except to the extent covered by earnings after

deducting operating expense and fair return. This is a matter of equity to be determined by a Court, and the Committee will not venture an opinion. If under regulation the property is a losing venture, it is not included in the class of properties now being considered. The depreciation existing will be found and reported, together with all pertinent facts, and the Court will determine the equities of the case.

Concluding Suggestions.—The valuing engineer should bear in mind that when a company owner has invested a reasonable sum in a property for public service, it is entitled to, but not guaranteed, a fair return on its investment, so long as the money remains in the property, either as property, or funds, or accrued public obligation to pay. Therefore, so long as the company owner keeps a sum equivalent to the total investment at work for the public, either as property serving the public, or funds held in reserve for such property, no policy should be followed in estimating depreciation that will reduce the property to a value less than the investment, or, when using cost of reproduction less depreciation as a basis of "fair value", to a value less than the cost of reproduction of that part of the property estimated to have been created with company funds, acquired by gift or in any way not the result of public contributions to cover depreciation.

Valuing agencies should also bear in mind the fact that for 30 years, until 1909, the Supreme Court of the United States not only recognized the replacement method as a proper method for the maintenance of public utility property, but disapproved the practice of charging the public with depreciation allowances in advance of the necessity for their use, holding that only money actually expended could be charged in operating expense and so collected from the public. In 1909 the Court apparently reversed itself in the Knoxville case. For the purpose of the present discussion, there is no need to speculate as to the strict applicability of this decision to all kinds of properties or property units, but it is thought to be proper to advise that valuing agencies should proceed in such a manner with respect to depreciation of properties that grew up under the law as it was before 1909, so that such properties shall not be unfairly reduced in value by strict application of a current interpretation of the Knoxville decision to all their parts. If the law changes, equity would seem to demand that the change shall not be retroactive; and it may be said fairly, we think, that though law must in general govern in all matters on which it speaks, yet, with respect to such matters as the details of valuation of public utilities, of which depreciation is one of importance, in the determination of which there never can be more than approximate results, and concerning which the minds of men have been and are changing, equity should not be ignored.

Appreciation.

Definition and Application.—Appreciation, as used in connection with the valuation of public service properties, according to the definition given in the Glossary "is generally restricted to physical items, and measures their gain in value due to age, use, and properly directed labor. Its principal application in connection with railroads is to roadbed, which, for instance, is increased in value by solidification and grassing of slopes."

Appreciation, therefore, represents the improvement in quality and usefulness of certain parts of the physical properties of a railroad or other public utility property, and it results from the lapse of time from work not specifically charged to capital account, from maintenance, from use, etc., and covers items not represented either by the quantities, or unit prices, that are determined in connection with a valuation.

Upon a railroad, appreciation is found in connection with roadbed, both in cuts and fills and in the modification of embankments; the general improvement of the slopes through various forms of protection of both embankments and cuts; and improvement of drainage facilities along the roadbed, and right of way in general.

In the case of irrigation works, appreciation may be realized upon dams, canals, and embankments, particularly when not originally built with great care.

Its determination is difficult, and care must be exercised lest any of the allowances be duplicated in development expense.

General Principles.—In the case of the San Joaquin, etc., Canal Co. *vs.* Stanislaus County, *et al.*, 191 Fed., 875, in which was involved the value of certain canals, the Company claimed that the earthwork had appreciated in value, the claim being that, by the lapse of time and by reason of the packing of the banks and the silting of the canals, an additional value had come, in the way of avoiding breaks and in preventing the loss of water by seepage. Judge Morrow, in reviewing the findings of the master, quoted from various Supreme Court decisions to the effect that a public utility property is entitled to earn a fair return upon the reasonable value of its property, at the time it is being used for the public, and added:

"We then have this rule for ascertaining the value of a plant of the character of that owned by the complainant in this case: Find the cost of reproduction as of the date of the use in question and then from this cost deduct the depreciation that has occurred from age and usage."

The master to whom the case was referred having determined that depreciation should be deducted, said:

"Likewise it would seem to me that if by reason of a lessened amount of depreciation, the canals of complainant in their present

condition are capable of delivering more water, thereby producing greater revenues to the Company, it would be of more value than a canal estimated on the basis of the reconstruction figures aforesaid."

The master, however, was not satisfied with the evidence submitted as to the amount of depreciation or appreciation, and held:

"After a careful examination of all the testimony on this question I find that I am unable to make either a calculation as to appreciation or depreciation of the earthworks of the canal and shall assume that the one offsets the other."

Circuit Judge Morrow, when he reviewed the case (page 855), stated:

"After carefully reading the testimony on this subject I have reached the same conclusion the master did with respect to this claim."

In this case, therefore, appreciation was acknowledged; but the one was considered to offset the other.

In the Minnesota Rate case, where the value of railroad property was sought to be determined through the cost-of-reproduction method, and where the Court below found that appreciation and depreciation existed in practically equal amounts, so that the one offset the other, Justice Hughes stated, in settlement of the matter:

"If there are items entering into the estimate of cost which should be credited with appreciation this also should appear, so that instead of a broad comparison there should be specific findings showing the items which enter into the account of physical valuation on both sides."

It appears from this decision that there can be no general offsetting of appreciation against depreciation, but that appreciation must be determined separately from depreciation.

Determination and Estimation of Appreciation.—It is now conceded that all items that are measurable by units, such as rip-rap, protection of slopes by sodding or other forms of vegetation, in whatever manner it has been secured, should be measured and unit prices attached, and the value of rip-rap, sodding, and other forms of slope protection should be determined in that manner; and that this method should be followed in valuing common carrier properties, and other public service properties, such as dams, protected embankments of reservoirs, etc.

There are two forms of appreciation that are particularly applicable to railroad properties; one is described by the terms "Solidification and Seasoning", and the other by the term "Adaptation".

Solidification and seasoning are found in railroad, canal, and other embankments, and along the slopes of railroad cuts. They are produced by compacting under the action of the elements; through use, such as the running of trains of a common carrier; through the skillful

direction of labor, of a common carrier or other public service corporation, in checking wastes on the slopes of embankments, and encouraging the growth of vegetation:—the final result being a solidified condition of the entire roadbed or other form of construction with greater compactness in the case of banks, and the drying out of cuts and the solidification of the slopes of cuts. The results of solidification and seasoning are a reduction in the cost of maintenance of the property of any common carrier, or the property of any public service corporation that receives any form of protection due to age and the action of the elements, combined with properly directed maintenance labor. Rip-rap becomes more settled, compact and secure; trees and shrubs, planted for ornamentation or snow protection, increase in usefulness and value with age and care. In railroad property a higher value is evidenced by the fact that trains can be run at greater speed and with greater safety; and that the expense of operation is reduced, and fewer accidents occur, after many years have passed since the property was a completed new one.

It is generally conceded that appreciation in the form of solidification and seasoning continues over a long period of years. For example, a railroad 40 years old is much better than one 5 years old. In measuring all forms of appreciation which may occur, however, it is necessary to have a full knowledge of what methods have been used by common carriers in process of construction and in the period of physical development following the construction period. A railroad property is not a finished product when the construction forces have put its parts together and turned it over to the operating department. The subsequent work done upon it, and the quantities subsequently added to it to produce the finished product, should be covered by the cost of reproduction rather than under appreciation.

Take, for example, the Virginian Railway, 444 miles long; tracklaying was started in 1905; train service was begun on some parts of the line in 1907; operation was begun under difficulties in 1910; ballasting, etc., was completed in 1915. In the 8 years (1907 to 1914, inclusive), during which physical development period the first stage of solidification was in progress, the excess cost of ordinary labor per mile of track totaled $1 630.

Again, on the Big Sandy low-grade line of the Norfolk and Western Railway, 59 miles long, tracklaying was started in November, 1903, and operation was begun under difficulties in 1904, with some construction work in progress until 1907. During the 3 years of the physical development period, while some construction work was still under way and the first stage of solidification was in progress, the excess cost per mile of ordinary section labor was $3 090 more than that during the 3 years immediately following.

The items of cost in general maintenance labor, such as these incurred during the period between the beginning of the operation of any portion of a railroad and the final completion thereof by full ballasting, etc., which generally covers a period of several years, is an item of cost to the property, whether it is charged to construction accounts or not; and it most frequently has not been so charged in the past. Hence, in determining the cost of reproduction new of a property, this item of cost, which will vary in different sections of the country, as shown by the two examples, the extreme case given being in a difficult country, so far as control of slopes is concerned, must be added to the cost of reproduction as determined by measurable units. Care should be taken in analyzing these costs that they may not be duplicated in reproduction cost or appreciation and in development expense.

In addition to this, however, there is an increased value that comes to such a property by reason of solidification and seasoning, due primarily to time and use, that continues for many years after the entire completion of a railroad.

Adaptation.—Adaptation is the adjustment of the physical property to its environment and purposes, and is brought about in the course of time by the action of the elements combined with labor. For example, in the case of a stream, where by successive floods the stream may deepen and scour out its channel and make more safe adjacent embankments. After a railroad is in operation, many changes are made in roads and drainage, as between the railroad and adjoining lands, all traces of which are lost in a few years thereafter; likewise, culverts originally built are found to be too small and are necessarily enlarged, or the approaches and outlets are changed. Briefly, therefore, adaptation is exemplified in improvement in drainage, both on the right of way and outside the limits of the right of way, which has been made from time to time by the forces of the railroad company or other public service corporations, the value of which cannot be determined by measuring items of quantity at the date of valuation. It is an item of charge to the cost of reproducing a roadbed or dams, canals, and embankments of the class mentioned, of the drainage area in connection with the dam of a water company. This class of appreciation should be taken into consideration along with solidification and seasoning.

The best method of estimating appreciation due to solidification, seasoning, and adaptation appears to be by comparing the cost of maintaining a new road, directly after it has been entirely completed, with the cost of maintaining an old road in the same district under similar conditions of traffic.

In one case of a western railroad the cost of maintenance of a new line, 175 miles long, was compared with the cost of maintenance of an

old line of the same length. In $2\frac{1}{2}$ years the excess cost spent on the new road, to make it comparable with the old one, aggregated \$1 400 per mile.

Another way is to assign a direct percentage to the grading quantities.

In California allowance was made of 2% a year for 5 years on all earth and loose rock quantities, and 1% per year on all solid rock quantities, for solidification and seasoning. This might be used as a minimum, to which should be added \$600 per mile for all roads more than 5 years old.

Care must be taken in estimating appreciation that items of labor and expense, included therein, may not be duplicated in development expense.

CHAPTER VII.

DEVELOPMENT EXPENSE.

The Nature of Development Expense.

The Committee recognizes two principal periods in the creation of a going concern operating a physical property for the production of a commercial commodity, be that commodity water, gas, electricity, sugar, textiles, or any other thing, or the transportation of persons, property, or thought. These two periods are:

1.—The construction period, which covers the interval from the inception of the enterprise to the beginning of regular operation.

2.—The development period, which covers the interval from the beginning of regular operation to the time when efficiency and profitableness of operation shall have been achieved.

Corresponding with the two periods recognized, the Committee divides costs into two classes—construction costs and development expense. The estimated cost of construction includes all costs incurred during the construction period, and, as will appear, may include certain costs incurred during the development period.

Development expense is of two kinds: (*a*) the cost of tuning up the physical property and bringing it to present operating efficiency; and (*b*) the cost of acquiring the business.

The cost of tuning up the property and bringing it to its present state of operating efficiency stops at the end of what may be called the physical development period, which is usually included within the development period as previously defined, and the cost may be included in the cost of construction.

The cost of acquiring the business usually extends throughout the development period, though there are cases in which a profitable business develops at the very beginning.

The physical development cost, which should be included as a part of the construction cost, comprises the items of work required to bring the property to an efficient operating condition, such as: the extra work required on new embankments to maintain tracks in proper operating condition; the cost of testing and sometimes of re-adjusting and remodeling all sorts of machines to make them operate properly, or to increase their efficiency; the making good of defects which have become visible after a property becomes operative; and a great variety of other expenses incidental to the first operation of a property, which are not incurred in subsequent years after that same property has reached full operating efficiency.

The Committee also recognizes going value, as defined by it, as quite independent of development expense, and discusses it in Chapter VIII on INTANGIBLE VALUE.

DEVELOPMENT EXPENSE AS A PART OF ORIGINAL COST.

On the basis of original cost, the development expense in any one of the early years when the earnings are deficient will be obtained by deducting the actual receipts from the gross amount that the owner of the property is entitled to earn in that year. Such gross amount is the sum of these items:

(*a*) The expenditures for operating expenses and taxes;
(*b*) A sum to offset the waste of capital through depreciation;
(*c*) A sum representing a fair return on the investment, including money, and the money value of services and of other considerations.

The difference between the actual and the fair gross receipts for the first year is the development cost for the year, which should be added to the investment at the beginning of the second year in order to obtain a basis for estimating fair return for that year. By following the same course for successive years, adding the development cost for each year until there is no further deficiency of earnings, a sum will be reached which will represent the amount of the investment at the end of the development period, and the difference between the investment at the beginning of operation and at the end of the development period will represent the development expense.

It should be noted that the development cost obtained in the manner recommended includes also the physical development costs of those years when the earnings were deficient. So far as possible, these should be separated from the total sum found, and included as a part of the construction cost of the physical property.

After the property originally built has attained adequate and steadily maintained earning capacity, the ordinary additions of subsequent years may involve little or no additional development expense, except for the cost of testing and tuning up plant units, because there will be no deficiency of earnings caused by such additions, but, from time to time, additions may be made of such magnitude that the earnings will again become temporarily deficient.

Losing Venture.—Fair dealing demands that the development expense actually incurred in tuning up and developing the business of a normal property be properly recognized, and the Committee believes there is no more equitable way of doing this under normal conditions than by including it as a part of the capital account. It recognizes, however, that there may be abnormal conditions under which this method should not be followed, as, for instance, where the net

receipts are unnecessarily low on account of bad management, or where bad judgment has been used in the location or design of the plant, so that the property is bound to be a "losing venture".

It does not seem desirable that the general rule should be modified because of these exceptions. In the application of the rule to specific cases, it will not be especially difficult to distinguish between profitable properties and distinctly losing ventures, but it may be difficult to distinguish legitimate development expense from the cost of bad management, in connection with those properties that are neither very profitable nor distinctly losing ventures.

Amortization v. Capital Charge.—It is sometimes urged that, although development expense is a real expense incurred in developing a property and its business, that part which is not a construction cost should be separated from other costs and repaid by means of earnings in excess of a fair return on the "fair value" of the property as soon as practicable after the business has increased to such an extent that excess earnings may be obtained by the maintenance of the previously existing rates. This requires the maintenance of the high initial rates for a longer period than would be necessary if the development expense is included in the return base.

When it is thus included, the deficiencies in the early years are made good by the greater earnings throughout all subsequent years, resulting from the larger return base on which earnings are predicated. The inclusion of development expense in the return base appears to have advantages in that it furnishes a more definite and simple method of accounting, and permits the adoption of normal rates at an earlier period than under the other plan. The cost of developing the business is just as much a part of the cost of producing the property, as is the cost of the physical items. Moreover, the Committee sees no reason, in principle or in equity, why this element of cost should be amortized, any more than the cost of the physical property.

Difficulties.—In the determination of development expense there may be difficulty in determining what is a fair return, not only because of possible differences of opinion as to what is a proper percentage to adopt as a return on investment, but because of the difficulty in determining a proper sum for the depreciation allowance to be used in computing the gross fair earnings. This difficulty is minimized if the attempt is made to determine these sums only for the first few years of the life of a property, when there is a deficiency of earnings, and is greatly increased if the attempt is made to determine the fair return and the proper depreciation allowances for a series of years, while the deficiencies are being offset. Practical attempts to determine the net excess or deficiency of earnings in a long series of years, in the case of properties of considerable age, have shown that a slight difference in the percentage assumed for the fair return will cause such very

great variation in the estimated development expense as to show that the method will not give trustworthy results when applied to most existing properties.

The Committee recognizes that public regulating bodies having control of both the accounting and the rate-making of the utility from the beginning of its operation may in the future adopt other methods which will offset such losses or amortize them, but these methods should not be applied to existing properties.

The Courts have ruled that the effects of regulation cannot be made retroactive, and that one cannot go into the "unregulated past".

Ames *v.* Union Pacific, 64 Fed., 165, 176 (1894). Mr. Justice Brewer. "The same rule controls if a railroad property is sought to be appropriated. No inquiry is open as to whether the owner has received gifts from States or individuals, or whether he has as owner managed the property well or ill, or so as to acquire a large fortune therefrom. It is enough that he owns the property, has the legal title; and so owning, he must be paid the actual value of that property. If he has done any wrong in acquiring or using the property, that wrong must be redressed in a direct action therefor, and cannot be made a factor in condemnation proceedings. These propositions in respect to condemnation proceedings are so well settled that no one ever questions them. The same general ideas must enter into and control legislation of the kind before us [rate regulation]."

Public Service Gas Co. *v.* Board of Public Utility Commissioners, N. J., 87 Atl., 651 (1913), which was sustained by the Supreme Court of New Jersey, 87 Atl., 657 (1913).

"But as we have indicated above, the business thus acquired must be regarded as a legitimate part of the property of the company. We cannot equitably project back into the unregulated past a nome of prices that might to-day be regarded as fair and adequate, and assume that actual rates exacted in the past, in so far as they exceed what are now deemed fair, have not lawfully become the property of the company. If these high rates in the past have been employed by the company to acquire an intangible property in the shape of extensive patronage, that expectation of patronage is theirs and on its fair value the company is entitled to a return. It may or may not be a subject of regret that regulation was so long deferred; but deferred regulation is no excuse for refusing at present to allow a fair return upon what is the lawful property of the company."

Therefore the Committee holds that development expense cannot fairly be assumed to have been amortized in the past in old properties by excessive earnings, and that it should be included in present valuation, whatever changes in policy as to future costs or increments in value may be made by the regulating body hereafter. Moreover, the Committee thinks that in future regulation it is sounder public policy not to amortize development expense.

The determination of the proper rate of return is a matter to be decided by the Courts or regulating bodies, and an engineer, in making an estimate of development expense in the manner recommended, should state the rate of return on which it is based, so that the Court or commission will have the means of modifying the estimate.

Development Expense as a Part of Reproduction Cost.

The foregoing discussion relates to development expense as a part of the determination of the original cost of a normal property, and, as it is a real cost in connection with the original property, it is also a proper element to include in reproduction cost, but the difficulties of determining the development expense of reproduction cost are greater than in the case of original cost, because of the assumptions which it is necessary to make.

Shall it be assumed that the development expense will be based on the conditions which existed when the various parts of the property were created, or on the expense that would be involved if the property were to be re-created under the conditions existing at the time of valuation? Shall it be asssumed that the existing business is ready and waiting, or that it has to be re-acquired at the time of valuation?

If the property under consideration has grown by additions made from time to time, so that it is now several times as large as when originally constructed, there would be, on the basis of the conditions which existed when the property was created, a large percentage for development expense in connection with the original property, because there had to be an actual acquisition of business at that time; but, on the other hand, there would be a very small percentage of development expense attributable to the additions.

If based on reproduction under existing conditions, the development expense would apply to the entire property reproduced.

The Committee believes, as already indicated, that development expense is a real cost in the production of a going property, and that it should not be ignored in the reproduction cost. It is somewhat difficult of determination in any case, by reason of the necessity of distinguishing between proper deficits and deficits due to management, in ordinary properties which are neither very profitable nor losing ventures, but no such difficulty of estimation should prevent its inclusion, when present, and when its amount is estimated as well as possible. It is especially a feature of valuation which should depend on reasonable assumptions based on known occurrences in connection with the property under consideration or similar properties in other cases.

Attitude of Courts and Commissions.

Development expense has been generally recognized in recent years by both Courts and commissions, usually under the title of "going

value". Sometimes these bodies have used the terms "going value" and "going concern value" to represent the intangible values of a going concern as compared with a dead one, but many times the terms are used with a meaning corresponding to the definition of development expense given by the Committee.

Going Value (Development Expense) Discussed.—A very complete discussion of going value is given by Judge Miller of the New York Court of Appeals in the Kings County Lighting case (People *ex rel.* Kings County Lighting Co. *v.* Willcox, 210 N. Y., 479, March 24, 1914). He gives (at page 492) the following definition of going value, which agrees closely with the definition of development expense adopted by the Committee, and the decision, although using the term "going value", may be considered as relating to development expense.

"I define 'going value' for rate purposes as involved in this case to be the amount equal to the deficiency of net earnings below a fair return on the actual investment due solely to the time and expenditures reasonably necessary and proper to the development of the business and property to its present stage, and not comprised in the valuation of the physical property."

This case was one in which an appeal was made from the Court below, and four questions were asked. The one relating to development expense was as follows (at page 481):

"(1) Was the relator entitled, upon the facts shown in the record, to have the commission make an allowance for going value in determining the value of the relator's property used in the public service?"

The opinion is too long to reproduce in full in this place, but the more pertinent parts are as follows:

"It is now generally recognized that 'going value', as distinct from 'good will', is to be considered in valuing the property of a public service corporation either for the purpose of condemnation or rate making, but there is a wide divergence of view as to how it is to be considered."

* * * * * * *

"The difficulty of determining 'going value' will not justify the disregarding of it. Rate making is difficult. But that will not justify confiscation. The difficulty, however, will lessen, as it does in most cases, when we cease to think about the subject vaguely. What then, is 'going value', and how is it to be appraised?

"It takes time to put a new enterprise of any magnitude on its feet, after the construction work has been finished. Mistakes of construction have to be corrected. Substitutions have to be made. Economies have to be studied. Experiments have to be made, which sometimes turn out to be useless. An organization has to be perfected. Business has to be solicited and advertised for. In the case of a gas company, gratuitous work has to be done, such as selling appliances at less than a fair profit and demonstrating new devices to induce

consumption of gas and to educate the public up to the maximum point of consumption."

* * * * * * *

"To view the matter in another aspect, take the case of a public service corporation with a plant constructed just ready to serve the public. It is going to take time and cost money to develop the highest efficiency of the plant and to establish the business. Three courses seem to be open with respect to rate making, viz.: 1, to charge rates from the start sufficient to make a fair return to the investor and to pay the development expenses from earnings, a course likely to result in prohibitive rates except under rare and favorable circumstances; 2, to treat the development expenses as a loss to be recouped out of earnings, but to be spread over a number of years, in other words, as a debt to be amortized, that involves complications, but would seem to be fairer to the public and certainly more practical than the first; 3, to treat the development expenses, whether paid from earnings or not, as a part of the capital account for the purpose of fixing the charge to the public. The last course would seem to be fairest to both the public and the company, as well as the most practical.

"It may be, as is urged, that a well-conducted enterprise will charge the cost of developing the business to operating expenses, and that it would open the door to an overissue of securities to permit the capitalization of early losses. In answer, it is sufficient to say that we are dealing, not with proper methods of bookkeeping, not with the proper capitalization upon which to issue securities, but solely with the fair return which the company is entitled to receive from the public. Treating a reasonably necessary and proper outlay in building up a business as an investment for the purpose of determining the fair rate of return to be charged is far from holding that it should be treated as capital against which securities might be issued.

"We do not say as matter of law that the third course above outlined should be adopted as an original proposition. That may present a question of economics, depending on the particular conditions involved. The commission in this case had to determine the rate to be charged, not by a new company with no business, but by an old company with an established business. The first question, therefore, to determine on this branch of the case was whether the company had already received a fair return on its investment. If it had received such return from the start, or if in later years it had received more than a fair return, the public would already have borne the expense of establishing the business in whole or in part, and to that extent the question of 'going value' for the purpose of fixing a present rate would be eliminated; for it must constantly be kept in mind in dealing with this problem that the company is entitled to a fair return and no more. If it has already had it, that is the end of the matter. If it did not receive a fair return in the early years owing to the establishment of the business, a subsequent rate must allow for that loss or it will be confiscatory."

The conflict in view, expressed in the concluding sentences quoted above, and the earlier citation from the U. S. Supreme Court, in Ames *v.* Union Pacific, 64 Fed. 165, 176, (1894), is to be noted.

Nevertheless, the Federal Court decision has been reaffirmed in a long line of later decisions, and would seem still to hold, as the position of the highest Court of the land.

Conclusions.

The Committee recognizes development expense as a possible, usual, and, in most undertakings, an unavoidable real cost in the production of a normal going property, and as quite distinct from going value as defined by it, and discussed in Chapter VIII upon Intangible Values. It is measured in nearly all cases by the difference between the amount which the company is entitled to earn in the early years and the amount which it actually does earn.

On the basis of original cost, if the accounts are available, the development expense can be determined from the accounts, taken in connection with estimates of the proper sums to be allowed for depreciation and for fair return on the investment. If the accounts are not available, the development expense must be estimated on reasonable assumptions based on known occurrences in connection with similar properties. It is commonly the case that the general conditions existing when the original property was created can be ascertained with sufficient accuracy for determining whether or not there were early deficits and approximately their amount.

For ordinary additions to the original property, in the case of a prosperous company, there would be no deficiency of earnings, but, from time to time, large additions might cause a temporary deficit which should be taken into account.

As development expense is a real cost of producing the original property, it should not be ignored in the reproduction estimate, and the Committee believes this to be especially a feature of valuation which should depend upon reasonable assumptions based on known occurrences in connection with the property under consideration or similar properties.

A determination should be made in regard to whether the property under consideration is a "losing venture" which cannot earn a fair return on the "fair value" of the property. In such a case, development expense cannot be obtained, because it is based necessarily on the theory of a fair return. In such cases, also, the development expense is unimportant, because the return is independent of the "fair value" of the property deduced either from original cost or reproduction cost.

It is not to be assumed that merely because the property failed to earn an adequate return for a certain number of years, the project was a losing venture. Thus many, if not most, water-works properties built prior to the Nineties, generally required a period of well over a decade to develop normal revenue. Their growth was slow during

the first 15 to 20 years in many cases, nevertheless it cannot be doubted that higher returns could have been collected from their consumers in the majority of cases had it been possible to raise the rates.

Properties vary greatly in respect to the length of time required for developing the business. Some classes of property, like street railways in or between populous cities, may develop their business to a profitable stage in a very short time, but in other cases, as, for instance, a great irrigation project in the Far West, it may be well known in advance of construction that it will take many years to reach the point where profitable results can be achieved. The difference between properties in this respect is obviously to be ascertained by a study of their history and of the history of similar properties.

CHAPTER VIII.

INTANGIBLE VALUE.

In addition to the physical elements of property discussed in the foregoing chapters of this report, there are certain elements of non-physical character that must be considered, and their bearing on the valuation of public utility properties explained. These elements of value are called "intangible" for the reason that they cannot be itemized, measured, and appraised, like physical units, but must generally be estimated by a study of the income account, the possible growth or appreciation in value of property, and other advantages, existing and potential, that attach to the location, environment, ownership, or control of the particular property to which they apply.

Meaning of "Intangible" as Used in Valuation.

The term "intangible" is used in the current literature of taxation to mean bonds, notes, stocks, and money at interest, which, if owned by a corporation whose property is being appraised, must certainly be classed as tangible in the inventory. In the valuation of public utilities, the word "intangible" should be understood as being restricted to its essential meaning of something incorporeal, not capable of direct or exact physical measurement, and in this report its meaning will be thus restricted.

The word "value" has been used very broadly in discussions of valuation and in Court decisions pertaining to the subject. There is a distinctly intangible basis for some of its meanings, and the Committee deems it proper to include the analysis of the word in this chapter.

The chapter then will cover discussions under the following heads:

Value—in general;
Franchise;
Going Value—Going Concern Value;
Good Will;
Efficiency, Favorable Business Arrangements, Design;
Strategic Location;
Leases, Easements, Traffic and Operating Agreements, Water Rights, Strategic Advantages, Other Privileges.

Value, Tangible and Intangible Bases.

Value may be said to rest on both tangible and intangible bases. Some meanings of the word are "excellence", "importance", "utility", "worth". Other meanings are "the desirability of a thing, as com-

pared with the desirability of something else"; "the degree of want felt for a thing, as shown by the relation of supply and demand"; and, commercially, "the price at which a thing will sell". This last is the "exchange value" of this report.

Still other authorized definitions are "the cost to produce"; "the amount of labor necessary to produce". These two definitions furnish the tangible basis for computing the "physical value". The definitions leading up to exchange value furnish the basis for the conception of the intangible element of the term.

We see by this that the conception of the tangible element of the value of a thing rests on its proper cost or on its production, while the exchange value, which includes all tangible and intangible elements of value, rests on the output of the thing or on the results of its operation. Estimates, in money, of these two conceptions may be said to approach the same objective from opposite directions and in an *ideal* public utility, where the actual net returns are just equal to fair income on investment, the figures should be equal. Such equality is obviously a proper aim of regulation. We have then this equation as *ideal* for the *ideal public utility of the future* under constant public regulation from the beginning, but not applicable in general to presently existing properties nor to any property without corresponding contractual obligations—

Tangible value—that is to say, proper cost, including development expense, less "depreciation of valuation".	=	Exchange value—that is to say, dependable net earnings, after deducting a proper depreciation allowance, capitalized at a rate of return, fair for the property in question.

Courts and commissions have striven to establish just valuations of corporate properties for various purposes, such as: a base on which return on capital shall be computed, or on which taxes shall be assessed; a sale made to the public, or against which securities shall be issued. This base has been variously called "fair value", "real value", "reasonable value", "the present value", "actual value", "the value", etc. In the great majority of cases, the properties being considered have been those not under full and continuous regulation in the past; and, where the last member of our equation has figured out larger than the first, the authorities have frequently allowed something for the excess of exchange value over tangible value which has grown up around the nucleus of the latter. This excess, when existent, is called by the Committee the intangible value pertaining to the property. Such additions to tangible value will be fully discussed later in this chapter. The object here is to differentiate clearly between the nature of tangible and intangible values in general, and

to show that both have distinct and legitimate meanings, but that the term "value", standing alone, may lead to misunderstanding of meaning unless qualified by a modifying adjective.

A broad basis for separating tangible from intangible values is that the former can be ascertained from the proper cost while the latter can only be computed from a study of the results which may flow from the use of the properties in question.

Exchange Value.—Exchange value is the desirability of the property, estimated in money, where there is a ready market for properties of the kind considered; exchange value is synonymous with market value, and may be said to be the price which a willing and intelligent buyer will pay a willing and intelligent seller. In the case of a utility property furnishing service to the public, this price will be a function of its existing or potential dependable net earning capacity, or of the additional earning power that may accrue to its owner through the control of the property in question. It is the second member of the above equation. If the property is operating under a limited franchise, the limit will have a bearing on the dependable feature of the earnings or other advantages, and the price will be discounted accordingly. It will be influenced largely by the intangible element in the value of the business as well as by the tangible value of the property measured by cost.

Since exchange value is determined by a consideration of dependable income and beneficial results, existing and potential, it will automatically include all intangible values pertaining to the property, so that the value of franchise, going value (not development expense), good-will etc., cannot be itemized separately in a schedule.

Fair Value.—The "fair value", of Courts and commissions is intended no doubt to meet the definition given in the Glossary: "A value which is fair to the parties affected". In very many cases where "fair value" has been determined by public authority it has been made up of the present cost value of the property, as nearly as that could be determined, with reasonable allowance for depreciation plus an addition for such intangible features as the controlling authority deemed proper to add to the tangible amount. It has been held time and again by Courts that the "fair value" of a public utility property cannot be determined by a mathematical formula, by which, it is reasonable to infer, is meant a precise estimate based only on an inventory of the physical property.

It will be noted that, in all cases where additions of an intangible nature have been made to the physical inventory, such additions have been in very round numbers; like $285 000 in the Kansas City Water case; $40 000 in the Newburyport Water case; $75 000 in the Gloucester Water case; $150 000 in the Bristol and Warren Water case; $15 000

in the Galena Water case, etc. The roundness of these sums suggests that they were not arrived at by mathematically capitalizing earnings, but by some process of compromise or adjustment which seemed equitable to the Court.

In no recent case before the higher Courts has a valuation been fixed for a public utility property by capitalizing earnings to the exclusion of consideration of its tangible value measured by cost. This procedure seems rational, for the reason that the "fair value" sought by the Courts and commissions is wanted for some purpose of regulation; and, as the object of regulation is to secure justice for both the owners and consumers, it is not conceivable that a value based simply on a consideration of the present or estimated net earnings could be taken as a just base for any of these purposes.

Present earnings may be too low to command capital or to maintain the existing enterprise, or higher than the service rendered may warrant. They are often adventitious, empirical, and based on what the patrons can or will pay. To use them as the sole basis for determining "fair value", would be to render regulation nugatory.

If it is held that fair earnings, for the property as a whole, might be assumed as a starting point, it is pertinent to inquire on what such earnings should be based, or how should they be assumed. It is difficult to use value of service, to the consumer, *per se,* because it cannot generally be computed or assumed, as it is generally intangible and without a basis from which to start. Heat and electric units, energy measured by horse-power and similar units, are constant the world over, and of service to mankind; but no one would claim that their money equivalent is the same everywhere. An inland city of New England, for instance, should pay far more for such units than should a city at the pit-mouth of a coal mine in West Virginia. This illustration means that the cost of service should gauge, to a greater or less extent depending on circumstances, the price or value of it. A substitute plant might furnish service at a less cost, but it has been shown that substitute plants do not generally furnish a safe criterion of value. Hence—in view of the impracticability of assuming fair earnings, and the difficulty, if not uncertainty, attending their computation by other means—the cost of service, as produced by the plant under review, should be accepted as generally the most significant measure of the value of the service, and of the fair earnings to be derived therefrom. The reasonable value for regulation purposes must be largely deduced from the cost basis, with proper consideration of all the attendant circumstances and conditions—as for instance, the value of water rights in regions where water for irrigation has come to have, in fact, a commodity value.

In the opinion of the Committee, *"fair value",* that is say, the valuation to be assumed in regulation, should be deduced in each case

as it arises, giving full recognition to the tangible values existing in the property, however acquired, and full recognition to the intangible values, so far as they are applicable to the purposes in mind; that *exchange value* should be deduced largely by a consideration of the beneficial results flowing, or reasonably expected to flow, from the use of the property; and that when the word "*value*" is used alone, the text or modifiers should show clearly, and to the extent that may be equitable, whether tangible or intangible value, or the sum of the two, is meant.

Franchise.

This term is defined in the Glossary as:

"The authority granted by government to a person or corporation to create and operate a public service property, to use public property, and often to condemn property."

A franchise of this kind frequently, either explicitly or by implication, grants protection from competition by similar enterprises.

Various Functions.—A franchise is said to be perpetual when it is so granted, or when granted for a very long period; limited, when its term is relatively short or definitely stated; and terminable, when it may be revoked at any time. Terminable franchises are often perpetual in fact, and are sometimes called "indeterminate franchises".

We may divide the possible functions of a franchise into three parts:

1. A license to do business, to operate a public utility, for instance, taking toll from consumers for its output;
2. A grant to use public property, like streets, for subways, pipes, tracks, overhead wires, etc.;
3. A protection from competition.

Generally, in the past, a franchise has been a free grant from the public, and the obvious inference is that the grantee shall perform the service contemplated at a rate to the public such that only a fair return on the capital and effort expended will be secured, including of course proper recognition of the risk involved. If it were supposable that consideration of a franchise would add materially to the capital base, so that rates for service would thereby be enhanced above a fair return, we should be confronted with the anomaly of the public granting a corporation the right of unlimited usury in its dealings with the public.

Court Decisions.—A leading decision of the United States Supreme Court, not concerned with rate regulation, plainly asserts that the franchise has value. In this case (Monongahela Navigation Co. *v.* United States, 148 U. S., 312, March 27, 1893), the Court said:

"So before the property can be taken away from its owners, the whole value must be paid; and that value depends largely upon the productiveness of the property, the franchise to take tolls."

This was a case of the United States taking over from the Canal Company a very old property, and the total award, which was much greater than the cost of reproduction of the physical property, was based on the profitableness of the plant.

In the New York Consolidated Gas case (Willcox *v.* Consolidated Gas Co., 212 U. S., 19, January 4, 1909), relating to rates for gas, the question of the value of franchises was treated at considerable length. This company was created by the consolidation of seven independent companies in 1884, and at that time the State authorities sanctioned the issue of additional capital to represent the value of the franchises as then determined to a sum amounting to $7 781 000. Later, in 1907, the value of the franchises of the company was under consideration, and it was assumed by a master in one case, and by the Federal Court in another, that the franchises had increased in value from the sum above stated to $20 000 000 and $12 000 000, respectively, the increase corresponding to the increase in the value of the physical plant. The United States Supreme Court, in 1909, sanctioned the continuance of the original $7 781 000 of franchise value allowed by the State authorities in 1884, for the reason that its capitalization had been authorized at that time, but it refused to allow any increase of franchise value due to growth of business after that time. The caution as to precedent contained in the second quotation below shows that the Courts are reluctant to recognize the propriety of capitalizing franchise values. The Court said (at pages 44 and 48):

"It cannot be disputed that franchises of this nature are property and cannot be taken or used by others without compensation."

"What has been said herein regarding the value of the franchise in this case, has been necessarily founded upon its own peculiar facts, and a decision thereon can form no precedent in regard to the valuation of franchises generally where the facts are not similar to those in the case before us. We simply accept the sum named as the value under the circumstances stated."

In the case of Kennebec Water District *v.* Waterville (97 Me., 185, December 27, 1902), the Court said (at page 218):

"It [defendant's claim] is that the value of a franchise depends upon its net earning power, present, prospective, developed and capable of development, at reasonable rates, that the value to be assessed is the fair value to the seller and not the buyer, and that 'just compensation' means full compensation for everything or element of value taken. * * * The appraisal must be made having in mind what we have already said concerning the character and duration of the franchise

and reasonableness of rates. While with these limitations, the owner is entitled to receive the value of the franchises, having reference to their prospective use as now developed, and to the future development of their use, consideration must also be had of the fact that further investment may be necessary to develop the use, and of the further fact that at any stage of development the owner of the franchise will be entitled to charge only reasonable rates under the conditions then existing. But, subject to such limitations, we think it should be said that the owner is entitled to any appreciation due to natural causes, such as, for instance, the growth of the cities or towns in which the plant is situated.

And further (at page 220):

"But we cannot assent to the proposition that the capitalization of income even at reasonable rates can be adopted as a sufficient or satisfactory test of present value. Such a capitalization would fix at the present time a specific value which would continue for all time to come, as a fixed and unvarying source of income, no matter how conditions may be changed."

In Spring Valley Water Works *v.* San Francisco (165 Fed., 667, October 7, 1908), the opinion, in discussing the question of franchise value in a rate case, after stating that a franchise, if it has value, should be taken into account in rate regulation as well as condemnation proceedings, said:

"Serious and perplexing questions arise when it is attempted to ascertain the value of the franchise and going business. Here very little has been settled by the Courts, except that each case must depend on its own special circumstances."

In these and other cases the Courts recognize the propriety of including intangible elements of value, but the reasonableness of the rates from which these values are derived is strongly insisted upon. In the case of the Monongahela Navigation Co., a very old property was at bar, and evidently great consideration was granted to long-accepted rates unaffected by regulation, on one hand, and, on the other, to the property rights growing up from these rates on the "innocent owner" idea. In general, the Courts have laid down no rule for fixing reasonableness of rates in these cases, nor for computing the value of a franchise.

Considering the money value of a franchise: as a license to do business, its value is vital, and cannot be measured in money; it is comparable to the value of the air we breathe; as a grant to use public property, it may carry with it costs, rent, fees, or obligations, the cost of which can be estimated. Such costs can hardly be called intangible, and should certainly be included in an inventory. Such a grant may also lessen the expense of installation which would be necessary if streets, etc., could not be used by the utility. This acts

to reduce the necessary investment. The third possible feature of a franchise, protection from competition, is the one that has probably given the principal money value to franchises in the past. It is the legal base for the monopolistic rights of corporations, and is the feature that calls for public regulation more than any other. Intangible values acquired under this phase of franchise have been recognized by the highest Courts to be the inalienable property of the present owners, as shown above, but, unless such values have been converted into physical property useful to the utility, the Courts are now very chary about admitting them to capitalization, as may be seen by the second quotation from the Kennebec Water District case given above. In fact, the principles of fundamental equities would seem to prohibit earning on intangible capital which is admittedly derived from anticipated earnings in excess of a fair return.

In fixing upon the "fair value" for a property, the license feature of a franchise can hardly be included; neither can the privilege to use public property, except so far as such privilege costs the grantee money. In fact, the grant is made purposely to lessen the otherwise necessary capital, and it would certainly be absurd to augment the capital by assuming an intangible value for the grant. The monopolistic feature is then the only base for intangible value pertaining to a franchise; and this cannot be computed separately from that arising from "going value" which will be discussed in the next section.

Going Value—Going Concern Value.

In very many discussions and Court opinions, this component of value has been hopelessly and blindly mixed with development expense, which latter the Committee has set up as a distinct feature. Clearness of understanding will be enhanced if the separation is adhered to.

Development expense is equivalent to expenditure of capital. Going value, on the other hand, is, in the minds of many, apparently, an indefinite something that a live business has, which a plant without business has not. The fact that a business is connected with its customers, house connections made in a water supply system, the breath of life put into the body, as some express it, seems to have an almost mystic significance to many. It has been called the soul of the enterprise, while the physical plant is the material body.

In the work of Henry Floy, entitled "Valuation of Public Utility Properties", 1912, the subject is discussed under four heads, at page 137 and following. These conceptions briefly and clearly set forth the different methods that have been adopted for discussing going value in rational terms and for measuring it in money.

They are:

First.—"A legal and economic, recognized value, usually determined in an approximate way, in addition to, and over and above the

value of the physical plant, resulting from the putting of said plant into actual and useful operation. The value may be based on merely an actual expenditure in dollars, or an estimated value indicating the worth of the service performed, in transforming the 'dead' into a 'live' income producing property."

Second.—"A very frequent use of the term 'going value' is that of 'capitalized losses', namely, the capitalization of losses incurred during the first few years after a corporation begins business."

Third.—"Going value has also been used to mean the value that obtains from capitalizing the present net earnings of a corporation, *i. e.,* the value of a created income."

Fourth.—"Although the trend of modern movement is toward the reduction rather than the creation of non-physical values, going values have been allowed, particularly in water-works appraisals, based on the present worth of estimated earnings including those of future business growth.

"The method consists in estimating the present worth of excess earnings of an existing plant compared with those of a hypothetical plant, between the date of valuation and the time the earnings of the assumed plant shall equal those of the existing plant."

These four interpretations cover the ideas that have been rather vaguely expressed by Courts, commissions, authors, and others, perhaps as well as they can be covered.

It will be seen that the first, second, and fourth are really founded wholly or in part on a conception of what the Committee has classed as development expense; and that the third is the "exchange value" of this report.

A careful reading of Court decisions, attorney's briefs, and opinions of engineers and authors on this subject, leads to the impression that lawyers and judges have generally leaned toward an appreciation of the intangible nature of going value as something inherent in a "system in successful operation and earning a revenue", while engineers and authors generally are disposed to look upon it as the cost of developing, not only the capacity to earn, but the market for the output as well.

Mr. Justice Brewer, National Water Co. *v.* Kansas City (62 Fed., 853, July 2, 1894), said:

"The fact that it is a system in operation, not only with a capacity to supply the city, but actually supplying many buildings in the city —not only with a capacity to earn but actually earning—makes it true that 'the fair and equitable value' is something in excess of the cost of reproduction."

On the other hand, Mr. Benezette Williams, in connection with the Dubuque Water-Works appraisal said, regarding the valuation of the Kansas City Water-Works, after describing the appraisal of the physical property:

"The commissioners, however, took into account the fact that the plant was in actual operation, with an established business and a long list of patrons, and added to the cost of replacement, which included a liberal allowance for contingencies, an allowance for interest on the investment for a time long enough to enable the business to reach the point at which it was found."

These two quotations typify the difference of conception that exists between many students of this subject. The first implies that the judge's conception of the amount to be allowed above reproduction cost was of an intangible nature, presumably to be determined by a study of the income. The other, representing more generally the engineer's view, based this addition on what the Committee considers tangible grounds of interest during construction and development expense. The Committee aims to clarify the subject by assigning all costs like those referred to in Floy's first class, as above, to the appropriate items of the reproduction schedule, and by classing the costs and losses of the development period as development expense and confining going value strictly to its intangible aspect, depending on a study of the income account which reflects the advantages accruing from enlarged business, social growth, and other factors of improvement and progress. Floy's third class does not exactly define the Committee's idea, because it means the whole exchange value of the property, while the Committee considers going value to be a sum that may be, under some circumstances, added to the appraisal of the physical property. It is the difference between the exchange and physical values, and includes and is the resultant of the intangible values pertaining to all the features discussed in this chapter. No division is possible between the value of franchise, favorable location, good-will, or the other elements of advantage. Their effects automatically add together to make up what is distinctly going value.

If, from the actual net earnings for a given year available for distribution there is subtracted a fair return on the reproduction cost, including therein all proper overhead charges, development expenses, and other tangible capital items, including appreciation in value, less "depreciation of valuation", the remainder will be a measure of the income from going value for that year. Whether or not such income may be capitalized and added to reproduction cost is debatable. If the remainder, thus obtained, is not zero, its algebraic sign will determine whether the going value is positive or negative in the case under review.

Going value derived from large earnings is legitimate and inevitable in competitive utilities, like the steam railroads of this country, steamship lines, and most manufacturing enterprises, the favorable location and good management of which give them advantage over rivals less favorably conditioned. In competitive enterprises the

favorably located and well managed one will naturally and properly receive a higher rate of return on its cost than the other one.

When several properties are to be combined in a single corporation, their exchange values seem to furnish the principal basis for adjusting the financial ratios between them.

Good Will.

This feature is defined as follows in the Glossary:

"In ordinary business, the good will represents the special value that a business has by reason of its popularity and the amount of business thereby attracted. It is a part of the value of a 'going concern'."

As applied to a department store or to professional practice, good-will is a large item of intangible value. In some kinds of competing utilities it undoubtedly has weight. Its effect in any case merges into the resultant described in the last section, and the conditions accruing among competitive utilities are the same with this as with going value. In monopolies the highest Court has decided that good will is not an element to be considered independently in the valuation. In the case of Willcox *v.* Consolidated Gas Co. (212 U. S., 19, January 4, 1909), Mr. Justice Peckham said:

"We are also of the opinion that it is not a case for a valuation of 'good will'. The master combined the franchise value with that of good will, and estimated the total value at $20 000 000.

"The complainant has a monopoly in fact, and a consumer must take gas from it or go without. He will resort to the 'old stand' because he cannot get gas anywhere else. The Court below excluded that item, and we concur in that action."

Efficiency—Favorable Business Arrangements—Design.

These features are important, and, together with good management, should be encouraged. They add largely to the intangible value of a property; being, in fact, a major factor in going value which has been discussed above.

It is often said that efficient, economical management is not encouraged by regulation; but this should not be the necessary result. The English method of gas company regulation called the "London Sliding Scale" is perhaps the most prominent attempt to encourage efficiency that has yet been tried. It was adopted in 1904 by a Legislative act of the State of Massachusetts in an arrangement with the Boston Consolidated Gas Co. At that time the price per thousand feet of gas was fixed at 90 cents, and the dividend to the stockholders of the company at 7%, and the provision made that if in any year the price was reduced below 90 cents the rate of dividend for the succeeding year might be raised one-fifth of 1% for each cent of reduction below 90 cents. Provision was made in the Act for creating a surplus fund, if the earnings were not entirely exhausted by the dividends allowed,

and for increasing the price to consumers, if necessary in the judgment of the Gas and Electric Light Commission. The Act, following English precedent, provides that additional stock may be issued with the approval of the commission, but such issue shall be sold at public sale under competitive bids; also that the standard price, the scale, and the dividend rate shall be subject to readjustment after ten years from the passage of the Act. At present (1916) the price of gas under this arrangement is 80 cents and the dividend rate 9 per cent. The regulating board has radical changes in the method of control under consideration. In England the scheme has been in operation for thirty years or more, and does not work with entire satisfaction, except for a limited number of years after its adoption. In some cases the companies have not increased dividends as the scale allows them to do, evidently on account of the possibility of competition from other producers. This shows that natural competition, left free to act, is the real regulator where competition may exist.

Though the group of factors named in the caption of this section adds greatly to the exchange or market value of a property, they cannot in general be separately included in an inventory of either original or reproduction cost; but where exceptional efficiency in design, construction, and management is manifest, its results, although intangible, should be recognized and encouraged by the regulating body.

Leases—Easements—Water Rights—Traffic and Operating Agreements—Strategic Location and Advantages—and Other Privileges.

These are often elements of substantial value. They are entitled to careful analysis and consideration in accord with their just dues. They are in the nature, however, of special problems, often highly complex and legal in character, varying greatly with locality, environment, and attendant circumstances. Therefore they will not be discussed in detail herein.

Conclusion.

With reference to intangible value as a whole, the Committee takes the ground that, in finding original or reproduction cost, there must be included first, the *tangible* elements (including development expense) to which cost can be assigned or which can be separately scheduled, with an attached value based on concrete facts; and, second, that pertinent facts, bearing upon the *intangible* values, should thereafter be developed independently, as an aid to the formation of sound judgment as to their value.

Exceptional efficiency—although practically difficult of recognition and compensation in any plan of valuation, and outside of strict engineering analysis—should be recognized by Courts and commissions, when appraising property.

GLOSSARY.

Accounting Cost.

See *Book or Accounting Cost,* under COST—INVESTMENT.

Accounting—Depreciation.

See DEPRECIATION ACCOUNTING.

Accounting—Methods of.

See DEPRECIATION ACCOUNTING.

Actual Cost.

See *Original Cost,* under COST—INVESTMENT.

Additions.

Structures, facilities, equipment, and other property units added to those in service and not taking the place of any property for like purposes.

See also BETTERMENTS.

Age.

Under EXPECTATION OF LIFE—LIFE TERM.

Amortization Fund.

See SINKING FUND.

Amortize.

To extinguish a liability or debt by means of a sinking fund. The word, however, is frequently used in connection with such extinguishment by other means.

Annuity.

An annual allowance or payment; generally an equal sum each year, such as the payment to a sinking fund.

Appreciation.

A general definition is gain in value or worth. As used in connection with the valuation of public service property, this term is generally restricted to physical items, and measures their gain in value due to age, use, and properly directed labor. Its principal application in connection with railroads is to roadbed, which, for instance, is increased in value by solidification and grassing of slopes.

The appreciation in land values will be called an *increment.*

Average, Weighted.

See WEIGHTED AVERAGE.

Betterments.

Physical changes in roadway, structures, facilities, or equipment, the object of which is to make the properties affected more useful, efficient, or safe, or of greater capacity.

Book or Accounting Cost.

Under COST—INVESTMENT.

Capital.

"A portion of wealth which is set aside for the production of additional wealth.

"While this is the sense in which the word 'capital' is used in economics, in bookkeeping the term 'capital account' is often used to mean assets on the credit or passive side which denote proprietorship."*

Working Capital.—The capital in the form of cash, stock on hand, and other current assets, which must be kept available for the operation, maintenance and administration of a property.

Capitalization Base.

Under VALUE.

Charges.

See OVERHEAD CHARGES.

Charter.

A grant of power by the proper authority to a group of individuals to become a corporation, in order that they may act as a unit for a specific purpose.

Compound-Interest Method.

See under DEPRECIATION ACCOUNTING.

Construction Period.

That part of the production or reproduction period extending from the inception of an undertaking to the completion of its construction and the beginning of its regular operation. The definition may apply either to a whole property, or to substantial parts of it constructed at different times.

This period is followed by the *physical development period,* in which are incurred construction costs necessary to bring the physical property to its present operating efficiency. (See Reproduction Period.)

Cost.

Cost-Investment.—In the case of a new public service property, in which nothing has been added or abandoned, the outlay incurred in creating the property, not only money outlay, but also the money value of services rendered and of other considerations involved.

In the case of old properties to which many additions have been made, and wherein many items of property have been worn out and replaced one or more times, either in kind or otherwise, these words, when not qualified, have no generally accepted meaning, and have been used by the Courts, commissions, and others in a very loose way.

* From "The Accountancy of Investment", by Charles E. Sprague.

The words are frequently qualified, as, for instance, original cost, actual cost, original cost to date, original cost plus improvements, but even these qualified terms appear to have no generally accepted meaning.

Book or Accounting Cost.—The cost as shown by the books. This necessarily depends on the method of bookkeeping used. It is frequently the case that book cost fails to include the value of services rendered in promotion and construction, for which no money payment was made, and such costs as those due to additions and betterments, interest on capital during construction, and the bringing of the property to its full present condition of operating efficiency, which may have been paid for, out of earnings or otherwise, but properly belong in the capital account. On the other hand, it may include charges for replacements which do not properly belong to the capital account, and may continue to include investment in property which has been retired without being credited on the books.

Cost of Reproduction—Reproduction Cost—Replacement Cost—Cost of Duplication.—The estimated cost of reproducing the property without deduction for the loss of value due to age or other causes.

Original Cost—Original Cost to Date—Original Cost Plus Improvements—Actual Cost.—These terms are often used interchangeably, though suggesting different things. The Committee believes that "original cost to date" and "actual cost" are the better terms and defines them as the cost of the original construction, plus all charges against capital proper, under approved accounting principles, for expenditures incurred thereafter, and minus all proper credits to capital for the cost of property which has been disposed of or otherwise retired.

Under this definition the "original cost to date" or "actual cost" of a property is the first cost of the identical property units now in use, including overhead charges. The former is a term used in the Federal Valuation Act, and may be authoritatively defined by the Interstate Commerce Commission.

Cost of Reproduction.

Under COST—INVESTMENT.

Current Repairs.

See REPAIRS.

Decrement.

See DEPRECIATION.

Decrepitude.

Decretion.

Under DEPRECIATION.

Deferred Maintenance.

A technical term used in connection with public service properties, representing the amount which must be expended in repairs and renewals to bring plant units to an operating condition normal for the character of service to which they are devoted.

Depletion.

Under DEPRECIATION.

Depreciated Value.

See *Remaining or Depreciated Value,* under VALUE.

Depreciation.

A general definition is lowering in value or worth. As used in connection with the valuation of public service property, it is the loss of value due to age and use, including the loss from deterioration, wear and tear, inadequacy, obsolescence, depletion, and other similar causes.

Discussion of depreciation generally includes, also, causes of loss of value or worth, and methods of depreciation accounting and of restoring the loss to the property or its owners.

The depreciation in land values will be called a *decrement.*

Accrued Depreciation.—Depreciation which has taken place. It may have reference to existing property only, or it may include also the abandoned property.

Decrepitude.—A term sometimes used in connection with public service properties as having a meaning similar to deterioration.

Decretion.—Loss of service life.

Deferred Maintenance.—See DEFERRED MAINTENANCE.

Depletion.—Permanent loss of value due to exhaustion, or permanent lessening of value, as, for example, of mining properties.

Depreciation of Valuation or Fair Depreciation.—The sum which should be deducted from original cost to date or from estimated cost of reproduction new, as a step in finding that which the courts have called "fair value".

Deterioration.—Reduction in the quality of a property unit or in its efficiency for service, due to its physical condition.

Fair Depreciation.—See DEPRECIATION OF VALUATION, *supra.*

Functional Depreciation.—Depreciation due to inadequacy, obsolescence, and supersession.

Inadequacy.—The insufficiency of a unit to perform fully the function required of it.

Obsolescence.—The condition or process by which units gradually cease to be useful or profitable as a part of the property, on account of changed conditions.

Physical Depreciation.—Depreciation due to deterioration, such as use, wear and tear, accident.

Supersession.—The substitution of a more profitable or efficient unit for the existing property unit.

Wear and Tear.—The physical deterioration of a property unit occasioned by its use.

Depreciation Accounting.

The branch of accounting by which loss of value is provided for or accounted for either wholly or in part. There are various methods, among which are:

1.—Replacement Method.—This method makes provision from the earnings for reimbursement for the cost, less salvage, of property units retired when they reach the ends of their service lives, whether for replacement or for any other reasons.

2.—Sinking-Fund Method.—This method makes provision from the earnings for equal annual depreciation allowances of such size for any property unit that if these allowances are invested in a sinking fund they will, *with accumulations of interest compounded annually,* amount to the cost, less salvage, of the unit at the time when it reaches the end of its estimated service life. In applying this method, it has been common practice to compute annuities upon a basis of original or reproduction cost and total service life, but the method applies as well if, at any time, actual value and remaining service life are used.

3.—Compound-Interest Method.—(The same as the *Equal-Annual-Payment Method* discussed in the Committee's Progress Report.) This method makes provision from the earnings for annual depreciation allowances, for any property unit, of such increasing sizes from the beginning to the end of its estimated service life that when the same interest rate is used for determining the return on capital and the depreciation allowances, the sum of the return and the allowance is the same in each year of such life. The rate of increase of the successive depreciation allowances is also such that the "present worth" of each is the same. The sum of the allowances *without interest* equals the cost, less salvage, of each unit when it reaches the end of its estimated service life.

4.—Straight-Line Method.—This method makes provision from the earnings for equal annual depreciation allowances of such size, for any property unit, that the sum of the allowances, *without interest,* will equal the cost, less salvage, of each unit when it reaches the end of its estimated service life. The annual depreciation allowances by this method are each equal to the cost, less salvage, of the property unit divided by the number of years of its expectation of life.

5.—Unit-Cost Method.—This method is based on the conception that the value of a plant unit should be decreased from year to year to such an extent that the cost per unit of output or service, taking into account all annual charges for interest, depreciation, repairs, cost

of operating, etc., shall be constant during each year of the estimated service life of the unit.

Depreciation Allowance—Renewal Allowance—Retiring Allowance.

The provision which should be made through the rates by which a sum may be taken from earnings periodically for offsetting the decrease in value or worth of existing plant units. In accordance with methods of accounting in general use by railroads for a part of their property, and by some other public service corporations, the annual decrease in value or worth is offset wholly or in part by charges to maintenance or renewal expenses.

Depreciation Fund—Renewal Fund.

A fund consisting of cash or other quick assets set aside for the purpose of renewing property subject to depreciation when it ceases to be serviceable. This fund appears in the asset column of a financial statement, and may have no direct relation to the depreciation reserve.

Depreciation Reserve—Retiring Reserve.

The excess of past charges to "operating expenses" for depreciation which have been credited to the depreciation reserve account, over and above those retirements which have been charged thereto.

Deterioration.

Under DEPRECIATION.

Development Expense.

A term which may be applied to all expenses incurred in developing a property. In this report, however, it is limited to the expenses incurred in developing the property and business after the period of regular operation begins. That portion of development expense incurred in tuning up the plant and bringing the property to present operating efficiency during the physical development period may be accounted for as a construction cost. To a large extent, development expense represents the deficiency in net distributable earnings below a "fair return" on the "fair value" of the property during the early period of operation after original construction, and after important betterment or reconstruction. In other words, it is the cost of creating the business.

Development Period—Physical.

See PHYSICAL DEVELOPMENT PERIOD.

Duplication Cost.

See *Cost of Reproduction,* under COST—INVESTMENT.

Equal-Annual-Payment Method.

Under DEPRECIATION ACCOUNTING.

Exchange Value.

Under VALUE.

Expectation of Life—Life Term.

These terms mean the estimated economically useful life of the different units or different groups of units of which a property is composed.

Age.—The length of time that the property unit has been in use. Sometimes referred to as past life.

Remaining Life—Remaining Service Life.—Generally, the difference between the age and the total expectation of life of a property unit; but, as the unit grows older, the estimate of remaining service life, sometimes termed future life, may be changed by the condition of the property at the time of its appraisal.

Expense—Development.

See DEVELOPMENT EXPENSE.

Expenses—Operating.

See OPERATING EXPENSES.

Fair Return.

This term is used to indicate the return to which the owner of a public utility is equitably entitled for the use of his capital, in view of the risks involved and the efficiency displayed in management.

Fair Value.

Under VALUE.

Franchise.

The authority granted by government to a person or corporation to create and operate a public service property, to use public property, and often to condemn property.

Going Value—Going Concern Value.

These terms have been given many definitions. Mr. Justice Moody, in the Knoxville case, referring to an allowance for the going concern, makes this statement:

"The latter sum, we understand to be an expression of the added value of the plant as a whole, over the sum of the values of its component parts, which is attached to it because it is in active and successful operation and earning a revenue."

The term "going value" has also been given a less comprehensive meaning, in the valuation of public service properties, making it correspond closely with what has been defined heretofore as "development expense"; for instance, Judge Miller, in the Kings County Lighting case, said:

"I define 'going value' for rate purposes as involved in this case to be the amount equal to the deficiency of net earnings below a fair

return on the actual investment due solely to the time and expenditure reasonably necessary and proper to the development of the business and property to its present stage, and not comprised in the valuation of the physical property."

The Committee defines the term as the difference between the exchange value and the physical value of an established and operating property, due to the *intangible* values—such as franchise, good will, efficiency, favorable business arrangements, designs, strategic location, leases, easements, traffic and operating agreements, water rights, strategic advantages, and other rights or privileges—in contradistinction and addition to the development expense (or *tangible* costs and losses of the business-acquisition, or development-period, which are to be included in the physical value of the property).

Good Will.

In ordinary business, the good will represents the special value that a business has by reason of its popularity and the amount of business thereby attracted. It is a part of the value of a "going concern".

Improvements.

Additions and betterments to an existing property.

Inadequacy.

Under DEPRECIATION.

Increment.

See APPRECIATION.

Intangible Value.

Under VALUE.

Inventory.

The schedule with items multiplied by appropriate prices.

Investment.

See COST—INVESTMENT.

Item.

Under UNIT.

Items—Measurable.

See *Measurable Items,* under UNIT.

Life—Remaining.

See *Remaining Life,* under EXPECTATION OF LIFE.

Life Term.

See EXPECTATION OF LIFE.

Maintenance.

The act of keeping a property in condition to perform adequately and efficiently the service for which it is used. The term may be applied either to the property units which are kept in such serviceable

condition by repairs or otherwise, or to the property as a whole which may be kept in such condition by the replacement of parts which become worn or otherwise inefficient.

Under the rules prescribed by the Interstate Commerce Commission for steam roads, the word "maintenance" has a broader significance, as maintenance expenses include:

"also the loss through depreciation of the property used in operations, including all such expenses resulting from ordinary wear and tear of service, exposure to the elements, inadequacy, obsolescence, or other depreciation, or from accident, fire, flood, or other casualty."

Maintenance—Deferred.

See DEFERRED MAINTENANCE.

Market Value.

Under VALUE.

Measurable Items.

Under UNIT.

Obsolescence.

Under DEPRECIATION.

Operating Expenses.

Strictly speaking, these are the expenses incurred in operating a property, for which its owner is entitled to receive reimbursement through sufficiently large earnings. In accounting, the term has been given a broader meaning to include all expenses necessary for the maintenance of the integrity of the property and its operation.

Original Cost—Original Cost to Date—Original Cost plus Improvements.

Under COST—INVESTMENT.

Overhead Charges.

This is a term used for expenses incurred in producing a property, which cannot well be included in the unit prices. The methods of accounting used in connection with the construction of public or public service works do not, as a rule, provide for the charging of such expenses as those for promotion, administration, engineering, interest. and many other things to the different property units, although they are necessarily a part of the cost of such units. In the preparation of estimates of cost provision must be made, also, for contingencies which experience has shown do arise during construction. Hence, the engineer, using all available accounts and records as a basis, can make the most accurate estimate of reproduction cost by applying unit prices which do not include these overhead charges, and adding for the different elements which make up the overhead charges such percentages of the total cost of the plant units or measurable items of property, otherwise obtained, as are warranted by experience.

Physical Development Period.

The period, following the construction period, necessary to bring any physical property to present operating efficiency.

Physical Value.

Under VALUE.

Plant Unit.

See UNIT.

Prices.

See UNIT PRICES.

Property.

See PUBLIC SERVICE PROPERTY.

Property Unit.

See UNIT.

Public Purchase Base.

Under VALUE.

Public Service Commission.

The general title given to a public body authorized by law to regulate or control the actions of individuals, corporations, or public bodies owning or operating public utilities. As a rule, the authority is conferred on special bodies, as, for example, the Interstate Commerce Commission, and the public service commissions which have been created in recent years in most of the States, but this authority may also be conferred on the governing bodies of cities, as, for instance, in California, where, by the provisions of the Constitution of the State, the supervisors of a city were until recently required each year to fix the rates for water supplied by public service corporations to such city and its inhabitants.

Public Service Property—Public Utility.

The popular names given to a property created, under the provisions of a general or special law, to furnish service to the public. The public utility may be owned or controlled by individuals, a corporation, or a public body.

Public Utility.

See PUBLIC SERVICE PROPERTY.

Rating Base.

See *Return Base* under VALUE.

Remaining Life—Remaining Service Life.

Under EXPECTATION OF LIFE.

Remaining or Depreciated Value.

Under VALUE.

Renewal—Renewal in Kind—Replacement.

Renewal.—The making new of plant units by replacing them with corresponding new units, although the term is sometimes used even when the new units are not altogether similar to those replaced.

Renewal in Kind.—Used to indicate that the renewal is made with an identical plant unit.

Replacement.—The act of replacing a plant unit which is going out of service, with a substitute which may be either identical with the unit replaced or different from it. A replacement which increases the value is classed as an improvement to the extent of its increased cost.

Renewal Allowance.

See DEPRECIATION ALLOWANCE.

Renewal Fund.

See DEPRECIATION FUND.

Renewal in Kind.

Under RENEWAL.

Repairs.

The process of mending or of restoring to a sound and good state. In connection with the valuation of a public service property, the word may have two very different meanings. It may mean either the mending and restoring of parts of a unit to keep it in a sound and good state, or the mending and restoring of the defective parts of the whole plant to maintain it in a sound and good state. The meaning intended is sometimes indicated by the context, and where not so indicated the difference in meaning is a source of misunderstanding.

The frequently used term *current repairs* refers to the repairs belonging to the time immediately passing, and, like the word repairs, may relate either to plant units or to the whole plant.

Replacement.

Under RENEWAL.

Replacement Cost.

See *Cost of Reproduction,* under COST—INVESTMENT.

Replacement Method.

Under DEPRECIATION ACCOUNTING.

Reproduction Cost.

See *Cost of Reproduction,* under COST—INVESTMENT.

Reproduction Period.

The period estimated as necessary for the inception, construction and bringing to present operating efficiency of any property. It em-

braces a construction and a physical development period and the period necessary to acquire the business of the utility.

Retiring Allowance.

See Depreciation Allowance.

Retiring Reserve.

See Depreciation Reserve.

Return Base.

Under Value.

Salvage or Scrap Value.

Under Value.

Schedule.

A detailed list of all of the items of property.

Scrap Value.

See *Salvage or Scrap Value,* under Value.

Service Life.

See Expectation of Life.

Sinking Fund—Amortization Fund.

A fund instituted and invested in such wise that its gradual accumulations will enable it to meet and wipe out a liability or debt at maturity. The term "sinking fund" is sometimes used loosely in connection with any kind of a fund which will reach the amount of a liability or debt at maturity, but should be used only in connection with a fund made up of annual or other instalments *which require the accumulation of interest* in order to reach the full value at maturity.

Sinking-Fund Method.

Under Depreciation Accounting.

Straight-Line Method.

Under Depreciation Accounting.

Supersession.

Under Depreciation.

Taxing Base.

Under Value.

Unit.

A subdivision of a plant or property consisting of a single article or item, or a group of articles or items. The subdivision of the plant or property into units, not necessarily the same for different purposes, for convenience in estimating cost or in estimating and placing depreciation. A *plant unit* is a subdivision of the *physical property*; a *property unit* a subdivision of either *physical* or *intangible* property.

The term *plant unit* generally relates to a complete unit like a locomotive, a building, or a dam, and not to the parts like the wheels of a locomotive, the windows of a building, or the earthwork or masonry of a dam.

The word unit may be at times synonymous with the word item, but frequently will include two or more similar or dissimilar items. For instance, a dam may be called a property unit, but, in estimating its cost of reproduction, its various parts, such as earthwork, masonry, paving, etc., would be entered as items in the schedule. On the other hand, an item in a summarized schedule often includes many units.

Item.—An article; also a separate article or entry in an account or schedule.

Measurable Items.—Items of physical property which can be counted or measured.

Unit-Cost Method.

Under Depreciation Accounting.

Unit Prices.

These are the prices or costs to be set opposite each plant unit of the schedule, as multipliers.

Valuation.

The general definition is the act of valuing. In connection with public service property, the word means the determination of actual or reproduction cost, depreciation, and the many other factors which affect "fair value" or the bases for estimating "fair return", permissible capital, public purchase price, or proper taxation and the determination of such "fair value" or bases.

Value.

Primarily defined in the Standard Dictionary as "the desirability or worth of a thing as compared with the desirability of something else". As the desirability or worth of a thing is usually estimated in money, this definition in the present case may be abbreviated to "the desirability or worth of a thing, estimated in money".

As indicated in the introductory chapter, the Committee is of the opinion that the confusion which has resulted from the use of the word, value, because of the many different shades of meaning that have been given to the word, is so great as to justify a modified terminology. It therefore recommends:

(*a*) that the meaning to be attached to the word value be the primary meaning as defined in the first paragraph, except when it is necessary to use the words "value" and "fair value" with the meanings assigned to them by the Courts;

(*b*) that, in so far as the practice of valuation is concerned, the word should not be used, except as above stated, without proper modifying words to indicate what meaning is intended;

(*c*) that the principal purposes of valuation being to furnish a basis for a purchase or rental price, to obtain evidence as a guide for rate-making or the determination of the reasonableness of rates, to furnish a basis for authorization of capital, and to furnish a basis for taxation—these bases not being necessarily the same and not being the equivalent of value in every case—the use of the word value should be avoided and the propriety of the following terms recognized:

Capitalization Base.—The sum on which capital securities may be issued or authorized.

Public Purchase Base.—The price which should be paid in the case of the purchase of a public utility by the public.

Return Base.—The amount on which the public service company is entitled to earn a "fair return". This is what the Courts have termed the "fair value", in various rate cases.

Taxing Base.—The amount which should be subjected to taxation. Under the laws of some States, the basis to be used for taxation of property is not its value estimated in money by any ordinary rules, but a sum determined in accordance with such laws.

Exchange Value.—The desirability or worth of a thing, estimated in money. (See also VALUE and MARKET VALUE.)

Fair Value.—As applied to a public service property, this is a technical term used by the Courts to express a base for rate regulation, public purchase, capitalization, or other purpose, which is fairly obtained and fair to the parties affected.

Going Value.—See GOING VALUE—GOING CONCERN VALUE.

Intangible Value.—Existing value which is not represented by physical property and is not measurable by determinable cost. Intangible value exists by reason of franchise, grants, contract rights, location, market, age, strategic advantages, and efficiency, and possibly other elements that give a property value.

Market Value.—This term, applicable only to a property for which there is a well-established market, has been properly defined as the sum which a willing and intelligent buyer desiring such property would give for it to a willing, intelligent and solvent seller.

Physical Value.—The value of the physical property in contradistinction to that of the intangible property. Riggs,* referring to the "physical property" element of value, says:

"This consists of those things which are visible and tangible, capable of being inventoried, their cost of reproduction determined, their de-

* "The Valuation of Public Service Corporation Property", by Henry Earle Riggs, M. Am. Soc. C. E., *Transactions*, Am. Soc. C. E., Vol. LXXII, June, 1911, p. 18.

preciation measured, and without which the property would be unable to produce the commodity on the sale of which income depends. This physical property is considered as an operating entity, and not as a collection of inert and partly worn-out equipment, and, being so considered, carries, as part of the physical value, those costs and charges which are an inseparable part of the cost of construction but do not appear in the inventory of the completed property."

This definition of physical property is broader than that sometimes given, which excludes the overhead charges. The Committee agrees with this definition of Professor Riggs, as all costs required to create the physical property and put it in its full present condition of operating efficiency should be included in determining the physical value.

Remaining or Depreciated Value.—The value of a property after proper deduction has been made for depreciation.

Salvage or Scrap Value.—These terms are often used interchangeably, but a distinction may be made that *salvage* is the net value which an article possesses for further use for utility purposes other than that for which it was originally used, or as a second-hand article; and *scrap* is the net value of an article no longer useful for service.

Wear and Tear.

Under Depreciation.

Weighted Average.

The average found by dividing the sum of the several products of a series of multiplications of variable factors, by the sum of the factors of one class.

Working Capital.

Under Capital.

APPENDIX I.

DEPRECIATION TABLES,*

BASED ON COMPOUND-INTEREST METHOD, HERETOFORE CALLED EQUAL-ANNUAL-PAYMENT METHOD.

ACCOMPANYING REPORT OF THE SPECIAL COMMITTEE ON VALUATION OF PUBLIC UTILITIES.

INTEREST COMPOUNDED ANNUALLY.

(" Value " is value at end of year ; " Dep." is depreciation during year.)

5-YEAR LIFE.

Age, in years.	Interest Rate. 4%		Interest Rate. 5%		Interest Rate. 6%		Interest Rate. 7%	
	Value.	Dep.	Value.	Dep.	Value.	Dep.	Value.	Dep.
0	100.0000		100.0000		100.0000		100.0000	
		18.4627		18.0975		17.7396		17.3891
1	81.5373		81.9025		82.2604		82.6109	
		19.2012		19.0023		18.8041		18.6063
2	62.3361		62.9002		63.4563		64.0046	
		19.9693		19.9525		19.9322		19.9087
3	42.3668		42.9477		43.5241		44.0959	
		20.7680		20.9501		21.1282		21.3024
4	21.5988		21.9976		22.3959		22.7935	
		21.5988		21.9976		22.3959		22.7935
5	0.0000		0.0000		0.0000		0.0000	
		100.0000		100.0000		100.0000		100.0000

10-YEAR LIFE.

Age, in years.	Value 4%	Dep. 4%	Value 5%	Dep. 5%	Value 6%	Dep. 6%	Value 7%	Dep. 7%
0	100.0000		100.0000		100.0000		100.0000	
		8.3291		7.9505		7.5868		7.2377
1	91.6709		92.0495		92.4132		92.7623	
		8.6623		8.3480		8.0420		7.7444
2	83.0086		83.7015		84.3712		85.0179	
		9.0088		8.7654		8.5245		8.2865
3	73.9998		74.9361		75.8467		76.7314	
		9.3690		9.2037		9.0360		8.8666
4	64.6308		65.7324		66.8107		67.8648	
		9.7439		9.6638		9.5782		9.4872
5	54.8869		56.0686		57.2325		58.3776	
		10.1336		10.1470		10.1528		10.1518
6	44.7533		45.9216		47.0797		48.2263	
		10.5389		10.6544		10.7620		10.8619
7	34.2144		35.2672		36.3177		37.3644	
		10.9606		11.1871		11.4078		11.6223
8	23.2538		24.0801		24.9099		25.7421	
		11.3989		11.7464		12.0922		12.4358
9	11.8549		12.3337		12.8177		13.3063	
		11.8549		12.3337		12.8177		13.3063
10	0.0000		0.0000		0.0000		0.0000	
		100.0000		100.0000		100.0000		100.0000

15-YEAR LIFE.

Age, in years.	Value 4%	Dep. 4%	Value 5%	Dep. 5%	Value 6%	Dep. 6%	Value 7%	Dep. 7%
0	100.0000		100.0000		100.0000		100.0000	
		4.9941		4.6342		4.2963		3.9795
1	95.0059		95.3658		95.7037		96.0205	
		5.1939		4.8660		4.5540		4.2580
2	89.8120		90.4998		91.1497		91.7625	
		5.4016		5.1092		4.8273		4.5561
3	84.4104		85.3906		86.3224		87.2064	
		5.6177		5.3646		5.1170		4.8750
4	78.7927		80.0260		81.2054		82.3314	
		5.8424		5.6330		5.4239		5.2162
5	72.9503		74.3930		75.7815		77.1152	
		6.0760		5.9146		5.7493		5.5814
6	66.8743		68.4784		70.0322		71.5338	
		6.3192		6.2103		6.0944		5.9722

* When the report of the Committee is finally printed, these tables will be extended to 25, 30, 35, 40, 45, 50, 60, 80, and 100 years.

15-Year Life.—(*Continued.*)

Age, in years.	Interest Rate. 4%		Interest Rate. 5%		Interest Rate. 6%		Interest Rate. 7%	
	Value.	Dep.	Value.	Dep.	Value.	Dep.	Value.	Dep.
7	60.5551		62.2681		63.9378		65.5616	
		6.5719		6.5209		6.4601		6.3901
8	53.9832		55.7472		57.4777		59.1715	
		6.8348		6.8468		6.8476		6.8375
9	47.1484		48.9004		50.6301		52.3340	
		7.1081		7.1892		7.2584		7.3160
10	40.0403		41.7112		43.3717		45.0180	
		7.3925		7.5487		7.6941		7.8282
11	32.6478		34.1625		35.6776		37.1898	
		7.6882		7.9261		8.1555		8.3762
12	24.9596		26.2364		27.5221		28.8136	
		7.9957		8.3224		8.6450		8.9625
13	16.9639		17.9140		18.8771		19.8511	
		8.3156		8.7385		9.1636		9.5899
14	8.6483		9.1755		9.7135		10.2612	
		8.6483		9.1755		9.7135		10.2612
15	0.0000		0.0000		0.0000		0.0000	
		100.0000		100.0000		100.0000		100.0000

20-Year Life.

Age, in years.	Interest Rate. 4%		Interest Rate. 5%		Interest Rate. 6%		Interest Rate. 7%	
	Value.	Dep.	Value.	Dep.	Value.	Dep.	Value.	Dep.
0	100.0000		100.0000		100.0000		100.0000	
		3.3582		3.0243		2.7185		2.4393
1	96.6418		96.9757		97.2815		97.5607	
		3.4925		3.1755		2.8815		2.6100
2	93.1493		93.8002		94.4000		94.9507	
		3.6322		3.3342		3.0545		2.7928
3	89.5171		90.4660		91.3455		92.1579	
		3.7775		3.5010		3.2377		2.9882
4	85.7396		86.9650		88.1078		89.1697	
		3.9286		3.6760		3.4320		3.1974
5	81.8110		83.2890		84.6758		85.9723	
		4.0857		3.8598		3.6379		3.4213
6	77.7253		79.4292		81.0379		82.5510	
		4.2492		4.0528		3.8561		3.6607
7	73.4761		75.3764		77.1818		78.8903	
		4.4191		4.2554		4.0876		3.9169
8	69.0570		71.1210		73.0942		74.9734	
		4.5959		4.4682		4.3328		4.1912
9	64.4611		66.6528		68.7614		70.7822	
		4.7797		4.6916		4.5928		4.4845
10	59.6814		61.9612		64.1686		66.2977	
		4.9709		4.9262		4.8684		4.7985
11	54.7105		57.0350		59.3002		61.4992	
		5.1698		5.1725		5.1604		5.1343
12	49.5407		51.8625		54.1398		56.3649	
		5.3766		5.4311		5.4701		5.4938
13	44.1641		46.4314		48.6697		50.8711	
		5.5916		5.7027		5.7982		5.8783
14	38.5725		40.7287		42.8715		44.9928	
		5.8152		5.9878		6.1462		6.2898
15	32.7573		34.7409		36.7253		38.7030	
		6.0479		6.2872		6.5149		6.7301
16	26.7094		28.4537		30.2104		31.9729	
		6.2898		6.6016		6.9059		7.2012
17	20.4196		21.8521		23.3045		24.7717	
		6.5414		6.9317		7.3202		7.7052
18	13.8782		14.9204		15.9843		17.0665	
		6.8031		7.2783		7.7593		8.2446
19	7.0751		7.6421		8.2250		8.8219	
		7.0741		7.6421		8.2250		8.8219
20	0.0000		0.0000		0.0000		0.0000	
		100.0000		100.0000		100.0000		100.0000

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

PROGRESS REPORT OF THE SPECIAL COMMITTEE ON A NATIONAL WATER LAW*

To the American Society of Civil Engineers:

Previous Report.—At the Annual Meeting, January 19th, 1916 (see *Proceedings* for February, 1916, page 97), a Progress Report, agreed upon by the nine members of the Special Committee, was presented. (This had already been printed in the *Proceedings* for December, 1915, pages 2747 to 2751.) The report pointed out the inadequacy of existing water laws, the relative importance of the uses of water, and certain general principles, concluding with a recommendation that the Committee be continued with instructions to include in its consideration State, as well as Federal water laws, and, further, that it be authorized to enter into co-operative relations with similar committees from other professional organizations.

Membership Reduced.—The Committee was continued, provision being made by action of the Board of Direction on April 18th, 1916, for its future activity. In the meantime, however, there was discussion of the advisability of reducing the number of members of such Special Committees, as it became apparent that with the widely scattered membership it was practically impossible to convene a majority of the Committee at reasonable expense or to produce effective action. As a result of this discussion, the number of members of this Special Committee was reduced from nine to three. (See *Proceedings* for August, 1916, page 415.)

Co-operation Initiated.—Upon the reorganization of the Special Committee, correspondence was undertaken with a view to entering into co-operation with similar committees of other professional organizations. In particular, the suggestion of the appointment of committees was made to the various National, State and local engineering

* To be presented to the Annual Meeting, January 17th, 1917.

societies, and also the Bar and similar associations. Some of these have responded, but in many cases there has been delay due to the necessity of calling special meetings and of making provision for discussion, before effective co-operation could be begun. All of this requires much time. At present the various organizations and their committees may be said to be getting under way.

The subject is so far-reaching, and the underlying principles so important, that few, if any, of the organizations and the committees desire to express an opinion immediately on the various questions involved. There is broad interest and appreciation of the vital relations of the subject to the Engineering Profession, as well as to the public in general. Such appreciation is accompanied by the expression that ample time should be afforded for the growth of a sound sentiment among engineers based on full consideration and discussion of various phases.

Pending Discussions.—Most of the principles outlined* in the Progress Report have been accepted, and the discussion now centers on the expansion of these and their application to existing conditions. One of the points which is attracting attention is the necessity of recognition in statutory law and in Court decisions of the diversion of water from one drainage system or water-shed to another. The attitude often taken in the past is that such action constitutes a trespass, and should not be permitted. Attempts are being made to bring out clearly the fact that diversions of this character are necessary to the public welfare and to the enjoyment of the full use of the water resources of the country. Similarly, the matter of providing the right of way for outlets for surplus water should be given greater consideration, so that public interest may not suffer from blocking the delivery of water across State lines.

More radical than other suggestions, perhaps, is that of the need of recognizing the condition that, with increase of population and rapid change in surroundings, there must be occasional readjustment; the laws should be sufficiently elastic to meet the common needs of the people, as developed from decade to decade. What is the most important need to-day may be less so during the next generation. Navigation, which has been of prime importance in one locality, may properly give way to the greater public needs of water for municipal supply, or for the production of crops to feed the people. The disposal of waste or sewage in the easiest or cheapest manner may of necessity yield to the higher needs of water supply; or, in some instances, the reverse may be the case. In particular, the pollution of interstate streams is a subject of increasing importance.

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* *Proceedings*, Am. Soc. C. E., for December, 1915 (Papers and Discussions), p. 2749.

The discussion along these and other lines, touched upon in the former Progress Report, indicates that the Committee has entered upon a course which, for results, demands long-continued, systematic, and intelligently directed efforts, mainly toward the diffusion of information, to be followed by discussion of these large matters by the great body of engineers. Any attempt to initiate legislation, especially that far-reaching in character, before the engineers as a whole have fully considered the underlying principles, would be unfortunate. The subject is so complicated and the members of the Profession in general have been so busy during the past year that, though many individuals have expressed deep interest, yet they defer expressing opinions, and ask that more time be given for deliberation.

There is a growing belief that, in Federal affairs having to do with the water resources of the country, there should be a consolidation of the work along the lines suggested by President Herschel in his Presidential Address of June 27th, 1916.* In this connection attention is invited to the pamphlet on "Water Laws—State and National" by Charles N. Chadwick, Commissioner of the Board of Water Supply of the State of New York, in which he advocates a National Board of Water Conservation.

The most important criticism of the Progress Report already prepared is that of the statement on page 2749† in which it is said:

"The Committee finds that the powers of Congress are so restricted by the lack of Constitutional authority that the enactment of a comprehensive law is now impossible."

The trend of the recent decisions of State and Federal Courts is toward recognizing that Congress, under the Constitution, has a larger legal authority in appropriating water than has been heretofore generally considered. In the early history of water litigation, controversies were determined almost wholly with reference to the rights of individuals, while the rights of the State or Federal Government, the source of power, were seldom if ever considered. In recent years, however, the idea of the adjudication of water rights by a general proceeding involving all claims, including those of the State as well as those of individuals, and which also determine what unappropriated water might be subject to State laws, have brought into consideration the rights of the State. The United States also has entered actively into the field of utilizing water in its own right, and has found it necessary to appear in Court to protect the rights which it claims, so that it has now become necessary to consider the Federal Government in connection with much water litigation.

* *Transactions*, Am. Soc. C. E., Vol. LXXX, p. 1306.

† *Proceedings*, Am. Soc. C. E., for December, 1915 (Papers and Discussions).

Continuation.—Full discussion of this and similar matters would be premature. It is therefore recommended that the Committee be continued with a view to developing many of the details into which the matter in hand ramifies.

Respectfully submitted,

Committee
F. H. Newell, *Chairman.*
W. C. Hoad,
John H. Lewis.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

DESIGNING AN EARTH DAM HAVING A GRAVEL FOUNDATION, WITH THE RESULTS OBTAINED IN TESTS ON A MODEL

Discussion.*

By James B. Hays, Jun. Am. Soc. C. E.†

James B. Hays,‡ Jun. Am. Soc. C. E. (by letter).‖—The deep interest taken in the paper is ample evidence that many engineers are always on the alert for any bit of information pertaining to this subject. All members of the profession will welcome any information based on fact, either from field experience or models; although the former is greatly to be preferred, the latter will furnish subject matter for deep study in almost any case, aiding the designer to base his judgment on something more than guesswork. The writer's object, in making this model and testing it, was to apply the results, not directly, but toward forming some definite theory regarding the flow of water under dams. Mr. Hays.

On one point all the critics of the paper seem to agree in objecting to the results, that point being in regard to the size of the model, etc. There is only one factor that might vary with a larger model as compared with the small one, and that is in regard to the loss of head due to the water entering the soil.

The writer would earnestly suggest to all interested to try the method used in these experiments for obtaining the correct proportions of soil for the impervious section, whenever the occasion or chance should arrive. An extremely dense mixture will be obtained, and this,

* Discussion of paper by James B. Hays, Jun. Am. Soc. C. E., continued from October, 1916, *Proceedings*.

† Author's closure.

‡ Boise, Idaho.

‖ Received by the Secretary, October 31st, 1916.

Mr. Hays. when properly placed, will hardly leave room for the hygroscopic moisture. When once saturated, the mixture will remain so for a long period, even though there is no water above the dam to force the water into it. This was the writer's experience. After soaking the model completely, the results did not seem to change, whether or not the model was left with a full head of water for 24 hours.

The writer has due respect for the "line of creep" theory, and realizes that many excellent structures have been built on that basis; but it certainly did not hold good for the upper row of sheet-piling, when the design is considered part by part; and, at the same time, the lower row of piling produced excessive results, which certainly were not caused by the upper row of piling being in place, other than that the total results were lower than if the lower row of piling had been the only one used. In other words, although the total results approached the "line of creep" theory, why did not either row of piling show a loss of head based on the same assumption? The only answer to this question, in the writer's opinion, is in the partly closed valve theory.

Imagine a pipe line with two valves; close the lower one nearly half way, and then close the upper one only one-eighth of the whole distance. The discharge is lessened, the velocity through the main portions of the pipe is lessened as a result, but the lower valve (corresponding to the lower sheet-piling) creates no small loss of head (assuming that the water is passing through the pipe and not standing still), which is represented by a high velocity through the valve. The upper valve does not have its full effect, does not produce the loss of head that it would were the lower valve not closed. The reason is that the water velocity is lowered by closing the lower valve for the entire pipe, consequently the quantity is less, and hence a lower velocity or loss of head is required at the upper valve to pass the smaller quantity of water, when compared with the original discharge. It is quite evident that the upper valve does not have the same effect on the lower one, although it does assist in lowering the total discharge. If the lower valve were closed still more, by an amount equal to the closing of the upper valve, and the upper valve were opened, the total loss of head would be greater than for the two valves partly closed, as just described.*

Extend the piling cut-off deep enough to leave only a very small opening between the bottom of the pile and bed-rock, and we have, horizontal 745 ft., vertical $2 \times 239 = 478$ ft.; then the total creep is 1 223 ft., and the gradient is 1 : 12.23. The loss of head due to the piling would be about 39 ft., whereas the actual loss of head could not fail to be far greater than the above figure. Extend the piling still deeper, leaving an infinitesimal opening under the cut-off for the water, and the results will depart still farther from the "line of creep" theory.

* "Treatise on Hydraulics", by Merriman, Art. 88; also *Transactions*, Am. Soc. C. E., Vol. XXVI (1892), p. 449.

It was for this reason that the writer discarded this theory, when it failed to hold out, and accepted the "partly closed valve" theory, which explained thoroughly the results obtained with the model. Mr. Hays.

There must be a limit to the "line of creep" theory somewhere, but it is not mentioned in any of the standard works discussing the subject. Weisbach's experiments show that a gate-valve closed seven-eighths produces a loss of head nearly 47 times as great as when closed only half way, the "line of creep" theory, under the same conditions, shows that the loss of head due to closing down seven-eighths is only one and one-half times the loss produced by closing half way.

That the leaky condition of the upper row of sheet-piling should be plainly visible from a great distance, and not to the experimenters, is strange. Attention is called to the notes below Tables 2 and 3.

The low heads reported for the points, H to K, were taken simultaneously with the readings for the other tubes, and the drain valve was closed, during all experiments and between days, and the leakage from the tank was nil.

All gravel larger than 1½ in. in diameter was removed from the material placed in the bottom of the tank, and 1 in. was the limit allowed for material in the section of the model. This was done in order to eliminate leakage surfaces for the water to follow, as they would be all out of proportion to the size of the model.

The quantity of water entering the vertical circular tank was the same as that leaving the drain at the time the readings were made. Time was allowed for the water to adjust itself to the conditions. Lowering the head on top of the soil in the vertical tank caused the water to lower in both tubes by the same distance. It was determined definitely that the water was not held up in the tank sufficiently to affect the readings of the lower tube at any time.

Water did not flow through the drain valve during the experiments on the model, as Mr. La Rue seems to have understood; this would have defeated the experiments entirely. Instead, the water-table was forced up to within a short distance of the ground surface below the dam to represent the actual conditions, as nearly as possible. Practically all the material comprising the foundation of the dam at the actual site is saturated. There is a definite underground stream flowing down the valley.

Where the upward pressure against the base of the dam was mentioned by the writer, it was meant to be inferred that it was the pressure on an imaginary plane, just as one would speak of the hydrostatic pressure at a certain point in a body of water.

Evidently Mr. Petterson disregards the writer's idea of making the down-stream section of the dam more stable by having a very small upward pressure beneath that portion, whereas, in designs such as Fig. 14, a very high percentage of the material in the down-stream section

Mr. Hays. is thoroughly saturated, because the hydraulic gradient is close to the surface. Assuming in both cases that a cut-off wall through the main portion of the structure will cause all percolation water to come under the dam, the hydraulic gradient is in both cases projected at a slope of 1: 10, beginning at the toe and extending up stream. In Fig. 15 the lower 225 ft. of the down-stream section just covers the hydraulic grade line. Mr. Petterson has taken his hydraulic grade line below the base of the dam apparently to indicate the upward pressure on the base, or the imaginary plane which we call the base. The water will rise in the body of the dam to an extent governed by the upward pressure at any point. Where y and z or y' and z' are respectively equal or nearly equal, it is readily seen that the water will rise in the body of the dam to the line as shown, z or z' above the base. Thus, the hydraulic grade line for the lower portion of the down-stream section of the section shown in Fig. 15, will be identical with the surface of the material constituting the dam. In an earth dam this would certainly be disastrous. Continue the gradient at the rate of 1 on 10 for the next 175 ft. under the portion with the 1 on 2 slope, and it will be observed that a large portion of this down-stream section will undoubtedly become saturated. Of the down-stream section of Fig. 15, it is computed that 453 cu. yd. per lin. ft. of material will be dry, that is, above the hydraulic gradient (1: 10). Fig. 17, which corresponds to the writer's second section, shows that 717 cu. yd. per lin. ft. of material in the same section will be dry. Mr. Petterson's arguments on this point convince the writer, more than ever, of the advisability of having as much material as possible in the down-stream section dry, in order to secure stability. Figs. 14 and 16 can be compared in the same manner, showing even greater advantages in favor of the latter, as very little of the material in Fig. 14 will lie above the hydraulic gradient. Material below the hydraulic gradient will lose about 50% of its weight, which might be exerted toward increasing stability, due to buoyancy. Using Figs. 14 to 17, the writer has prepared Figs. 23 to 26, on which the hydraulic gradients are drawn through the down-stream section, in order to show the dry and saturated sections in each case.

Regarding the possible underflow to be expected under the finished structure, it would seem that several engineers have jumped to conclusions in this matter. Assume that the water flows through the foundation material of the dam in the same manner as through a large bundle of very small pipes. These pipes will have such a small diameter that capillary action will have a great effect proportionately, and the velocity of the water will be so low that the discharge will vary directly as the first power, rather than the square—this being an elementary rule in hydraulics. The length of flow and the increased

head in the proposed final structure will be proportionate, hence there will be the same loss of head per unit of distance along the base of the dam; but multiplying the area through which the discharge takes place will produce different results from those obtained by taking the required number of bundles of pipes. Two pipes having the same total area as a larger pipe will not have the same capacity as the Mr. Hays.

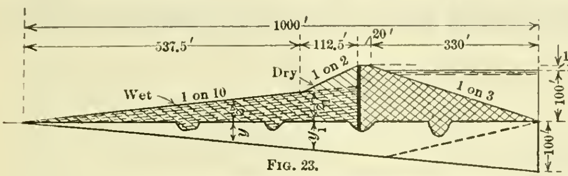


FIG. 23.

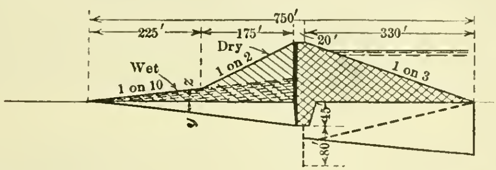


FIG. 24.

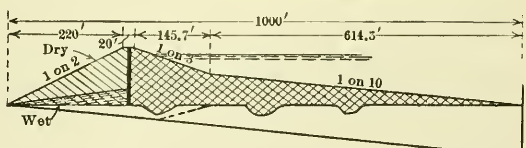


FIG. 25.

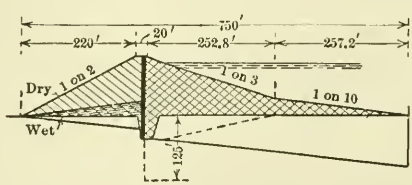


FIG. 26.

larger pipe—assuming, of course, that the loss of head per unit distance is the same in each case. The velocity is higher in the larger pipe, with the same loss of head per foot, than in the two smaller pipes.

Many of the criticisms of the tests are well taken, but the writer hoped for more discussion containing real meat, rather than theory. It will undoubtedly be a long time before anything definite can be decided which will furnish a sound basis for sheet-pile cut-off walls,

Mr. Hays. under similar conditions, other than the information now available. As mentioned previously, the "line of creep" theory is not yet to be discarded, but it has not yet been practically proved, except as regards the fact that dams, well built, and following that theory, have stood the test. Actual records of the loss of head due to piling seem to be lacking, and this is what the writer wanted to know when the tests on the model were attempted. He is firmly convinced that tests on a large model of the same structure would show similar results, aside from the entry head.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE DESIGN OF A DRIFT BARRIER ACROSS WHITE RIVER NEAR AUBURN, WASHINGTON

Discussion.*

By W. J. Roberts, M. Am. Soc. C. E.

Mr. Roberts.

W. J. Roberts,† M. Am. Soc. C. E. (by letter).‡—The author has given such an excellent description of this unique structure, the Drift Barrier, that little of value can be added.

H. M. Chittenden, M. Am. Soc. C. E., has also given a clear description of the flood problem to which the Drift Barrier pertains.||

The funds for improving the White, Stuck, and Puyallup Rivers are provided by a joint agreement between King and Pierce Counties, Washington, 60% being paid by King and 40% by Pierce County. A sum of $250 000 is available each year for 6 years, and a maintenance fund of $50 000 a year for 99 years is provided.

The improvement was begun in January, 1914, and the largest expenditure to date has been for the rectification of the river.

Closely following the dredge, the banks of the new channels are protected from erosion by concrete paving on the slopes and a brush mattress at the toe, ballasted with rock.

The rainy season of 1915-16 brought four high waters, one of which was higher than any since the flood of November, 1906. The Barrier was tested severely by these floods, and demonstrated fully its value and efficacy.

Its location has been questioned by Gen. Chittenden. At the site chosen by the Chittenden Board in 1907 a diversion dam has since been

* Discussion of paper by H. H. Wolff, M. Am. Soc. C. E., continued from August, 1916, *Proceedings*.

† Tacoma, Wash.

‡ Received by the Secretary, November 13th, 1916.

|| *Proceedings*, Am. Soc. C. E., August, 1916, p. 1083.

Mr. Roberts. constructed to prevent further flow of White River northward. The present site was chosen for the principal reason that it was feared such a structure, at the site originally selected, would jeopardize the diversion dam. The criticism that changing the site to a point 3 miles up stream would leave drift-producing territory below it, is a natural one. It should be noticed, however, that Figs. 12 and 13, are reproductions from photographs of drift-producing territory below the original proposed site for the Drift Barrier. This territory, as well as the entire channel from the Barrier to the Sound, must be thoroughly cleared before the improvement is completed. The removal of these "wrack heaps" is expensive, but is fundamental in rectifying a stream of this character.

Fig. 14.—Same View as Fig. 12, After Clearing River Channel, 1 Mile Below Diversion Dam.

Fig. 15.—Same View as Fig. 13, After Clearing River Channel, 2 Miles Below Diversion Dam.

FIG. 16.—2 040 CORDS OF DRIFT COLLECTED WITHIN A RADIUS OF 800 FEET, AT POINT SHOWN ON FIG. 12, 1 MILE BELOW DIVERSION DAM.

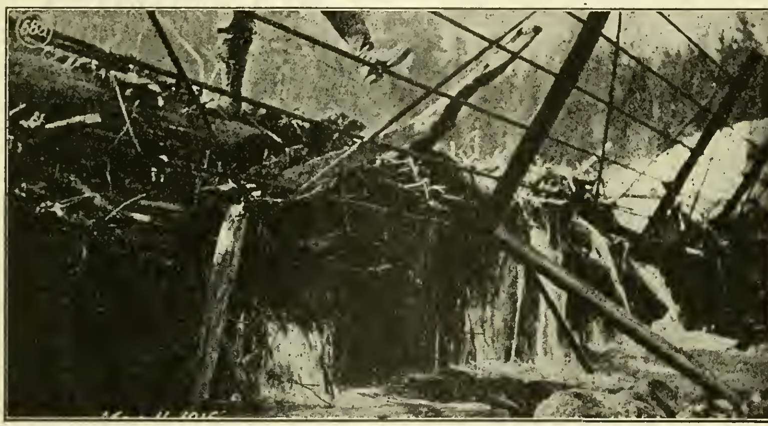


FIG. 17.—DRIFT BARRIER: DRIFT ACCUMULATION, MARCH, 1916.

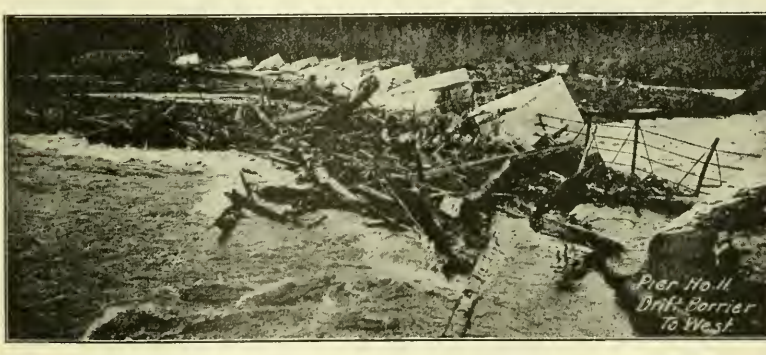
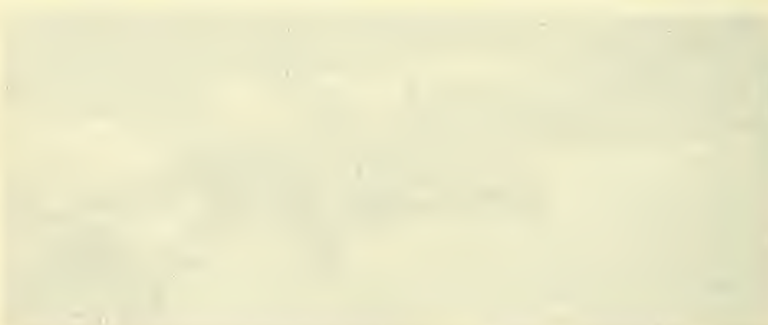


FIG. 18.—DRIFT BARRIER, MARCH, 1916.



AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE PRESERVATION OF SANDY BEACHES IN THE VICINITY OF NEW YORK CITY

Discussion.*

By Messrs. B. F. Cresson, Jr., and Elliott J. Dent.†

B. F. Cresson, Jr.,‡ M. Am. Soc. C. E. (by letter).‖—The question of beach protection raised in this paper is one of great importance to the State of New Jersey, and for several years the condition of the beaches has been under observation by the New Jersey Harbor Commission and its successor, the New Jersey State Board of Commerce and Navigation. Mr. Cresson.

Particularly was this matter earnestly studied during the winter of 1914-15, when great damage was done to the northerly New Jersey coast between Long Branch and Sandy Hook. The damage was especially great at Seabright, but serious erosions occurred along the Southern New Jersey coast, notably at Longport and Stone Harbor. Plans were prepared by the New Jersey Harbor Commission in 1915 indicating a form of coast protection and urging a comprehensive plan to be adopted in order that the beach might be saved and built, instead of being damaged by the various types of coast protection which have been placed without reference to each other and to a general plan. Each individual property owner usually had his own plan prepared and his own structures built without respect to his neighbor, and the damages that were done were due, at least partly, to the lack of a general study and a general plan. This is notably the case in the vicinity of Seabright.

* Discussion of the paper by Elliott J. Dent, M. Am. Soc. C. E., continued from September, 1916, *Proceedings*.

† Author's closure.

‡ Jersey City, N. J.

‖ Received by the Secretary, October 21st, 1916.

Mr. Cresson. The writer has read this paper with much interest and considers it a valuable contribution to the somewhat meager literature on this subject, but is compelled to take exception to some of the author's conclusions.

The opening paragraph of the paper states: "The object of this paper is * * * to emphasize the damage that must inevitably result to the beaches as a whole if the erection of structures that interfere with littoral drift is allowed to continue", and, supporting this statement, the author says:

"In order that littorally drifting material may pass a jetty, or a groin, it is necessary for it to travel into deeper water than would be the case on an unobstructed beach, and this deflection reduces the probability of its ever being returned to the beach. For these reasons jetties and groins must inevitably cause a wastage of beach material."

Although this may be the case with high jetties or groins, the writer has observed that it does not apply with low groins. Where low groins are used, and where there is a drift of the sand, the tendency is to build up a beach and numerous instances show it. Groins, 1 or 2 ft. above the level of the sand, will allow the current to pass over them, and, in doing so, retard the speed of the drift; then the sand in suspension will be deposited on both sides of the groin. There are numerous instances to show that this is the case.

The groins which the Central Railroad Company of New Jersey has recently built in the vicinity of Monmouth Beach have already commenced to gather sand, and, in conjunction with a sloping bulkhead, appear to be the most effective method of reclaiming the beach and stopping erosion.

The writer can scarcely agree with the following conclusion by the author:

"It would seem that the only salvation for many sections of that beach lies in the construction of sea-walls of sufficient strength to combat the waves until such time as new berms are formed, if such time ever comes."

The writer believes that a combination of low groins and a bulkhead or sea-wall with a sloping, curved, or broken face, so that the receding waves may not scour at the toe of the wall and carry the sand to sea by the undertow, is the most effective method of gathering beach and of protecting the foreshore. Neither groins alone, nor bulkheads alone, will accomplish this result, in the writer's judgment, under conditions such as exist along the New Jersey coast.

Instead of attempting to combat the waves by the strength of a heavy sea-wall, the writer believes it is far better to attempt to guide the forces of Nature by permitting the sand to collect in front of the bulkhead by the placing of low groins; the sand itself will then form a protection for the bulkhead.

ELLIOTT J. DENT,* M. AM. SOC. C. E. (by letter).†—In the first paragraph of the paper, its application was limited to that portion of the New Jersey shore north of Asbury Park. Asbury Park should have been included, as that beach was visited on several occasions, and the remarks and conclusions are applicable to it. Mr. Dent.

The discussion has been directed principally toward the writer's remarks in regard to groins and the detrimental results that must inevitably result if structures interfering with the littoral drift are erected along the beaches under consideration. Before taking up the discussion in detail, a few additional general remarks in regard to littoral drift are necessary.

Littoral drift is generally spoken of as though it were of constant magnitude; beaches are referred to as being in equilibrium, due to the fact that the littoral drift brings to them as much material as it takes away. As a matter of fact, no such equilibrium will be found to exist along beaches around New York City; such beaches undergo erosion for a period of years, and subsequently there is a period of accretion; the growth and denudation of the beach occur in what may be styled "cycles". The cause of these cycles is apparently the progress of sand waves along the shore. If the point where the temporary berms are widest is called the crest of a sand wave, and the point where the semi-permanent dunes are subjected to attack is called the trough, two such waves were in evidence during the summer of 1915. In one case the trough of such a wave was traveling along the sea wall at the south end of the Sandy Hook Military Reservation, while wide berms, corresponding to the preceding crest, might have been seen a mile or so farther north. At Long Beach, temporary berms of considerable width existed in front of the boardwalk and for a distance of perhaps 2 miles to the east; the berms then disappeared, and, for a considerable distance, the sea was making a direct attack on the semi-permanent dunes; still farther east, in the vicinity of Point Lookout, wide berms were again in evidence.

The material comprising the temporary berms is loose and friable, but when they have been removed, the remaining beach material along the New Jersey shore will be found to contain a large percentage of gravel, which offers considerable resistance to further erosion. Whatever may be the cause of the added resistance, the beaches along the Long Island shore appear to be much harder and much less susceptible to erosion after the temporary berms have been removed than they are while such berms are in existence; the temporary berms are loose under foot, and walking along them is a considerable labor, while, at the same elevation, where the berms have been removed, the beach will be found to be fairly compact and the walking easy.

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* Little Rock, Ark.

† Received by the Secretary, November 4th, 1916.

Mr. Dent. Suppose, for example, that an engineer has been called on to design works for the protection of a beach 1 mile in length, and that, due to the passage of the trough of a sand wave, this frontage has been subjected to an attack. Suppose, further, that the crest of a new sand wave is approaching. If no interests other than those of this particular mile of beach are to be considered, it may be feasible to stop the passing of the littoral drift by the erection of a jetty of such height and length that no sand will pass around or over it until the windward beach has grown up to the desired extent. The cove formed on the windward side of this jetty having been once filled by the littoral drift, and the shore line having advanced to the end of the jetty, the drifting sand would proceed around its end, and would eventually travel along the leeward beaches as though no obstruction had been created.

For the protection of such a beach, Mr. Higgins proposes the use of groins. According to him, such groins will cause the line marked "Plunge Point", on Fig. 7, to advance seaward, and the other lines to advance a similar distance. Mr. Higgins states that the quantity of material required to extend the beach "a few hundred feet" is "negligible".

Conceding for the moment that the line marked "Plunge Point" and the other lines of the beach may be moved seaward by the construction of groins, the following propositions will logically follow:

(*a*).—The material used to build up the beach is the same in the case of the jetty as in the case of the groins.

(*b*).—On account of the increased depth of the reclaimed areas, as compared with the depths over the areas that would have been reclaimed by the natural berms, the former area will be less than the latter.

(*c*).—Fixation of the drifting sand to reclaim the artificial beach will postpone for a corresponding period the date when the leeward beaches will receive a new supply of material.

(*d*).—Dependent on the particular location, the length of beach benefited may be less than that injured.

If the drift was passing in a steady stream, the erection of a jetty or of a system of groins (still assuming for the sake of argument that a system of groins will check the littoral drift) would result in the creation of an artificial trough, and the leeward beach would be subjected to the attack which always accompanies the passage of such a trough. Other conditions might be assumed, but the conclusions would be in no wise modified.

Any structure that stops and retains the littorally drifting sand in front of any particular property must inevitably induce an attack on the leeward property. It is an extraordinary fact that though the stoppage of the littoral drift by a jetty is so generally recognized as

being detrimental to the leeward beaches, it is claimed, nevertheless, by numerous writers, that the stoppage of the same drift in front of the same property may be effected by the use of groins without damaging the leeward property. Mr. Dent.

Turning now to the questions raised as to whether groins will actually check the littoral drift and cause an accretion to the beach in one case, or whether a system of groins will retard the erosion of an existing beach in another case, it will be well to examine into the results actually visible along the Long Island and New Jersey shores.

The sea-wall at the south end of the Sandy Hook Reservation has been referred to several times. Since the paper was written, it has been learned that, in 1901, six timber groins, of the type usual along the New Jersey shore, were built near the north end of that wall. The writer visited the locality several times, during 1914 and the first half of 1915, and the groins were buried so completely that their presence was not suspected. The fact that, after the erection of the groins, the beach was extended seaward until they had been completely buried so that they were no longer able to affect in any manner the growth of the beach, and the fact that the growth of the beach did not stop there, would indicate that the groins were not the primary cause of the accretion. The alignment of the beach would have led to a similar conclusion if the existence of the groins had been known.

In May, 1915, erosion was taking place along the face of this sea-wall, as described on page 641.* The trough of a sand wave was traveling north along the shore. As this trough continued its northerly course, it encountered the first groin of the group. The existence of the groin did not stop the erosion. By November two groins had been exposed for their entire length and a part of a third one was bared. The writer has no information as to what has occurred since 1915, but here is a case where there is strong presumptive evidence that the growth of the beach was due to causes entirely independent of the erection of groins, and there is positive evidence that the groins were impotent, so far as the preservation of the beach was concerned, when conditions had so changed that a period of erosion was due.

Mr. Haupt states that jetties similar to the one shown in Fig. 10, at Long Beach, Long Island, are now "buried out of sight". The writer in 1915 walked the entire length of Long Beach, from Point Lookout on the east to East Rockaway Inlet on the west, and noticed no evidence of their existence. As in the case of the Sandy Hook groins, the fact that the Long Beach structures were completely buried creates a presumption that the growth of the beach was due to some cause other than their construction. Mr. Haupt has described† certain

* *Proceedings,* Am. Soc. C. E., for May, 1916.

† *Proceedings*, Brooklyn Engineers' Club, 1913.

Mr. Dent. shore protection works at Edgemere, Long Island, and has presented a map showing that shortly after the erection of these structures there was a material growth along the corresponding frontage. The same map, however, shows that the growth of the beach, along the frontage which it was aimed to protect, was not measurably greater than that of the beach during the same period for a considerable distance east and west of the protected section. Is this not presumptive evidence that the accretion noted was due to causes entirely independent of the erection of the works designed by Mr. Haupt?

The hooked jetty shown in Fig. 10 was by no means buried at the time the photograph was taken. If any accumulation took place after its erection, no evidence has been presented to show that it was due to the presence of the structure. The evidence furnished by this photograph would indicate that there was a considerable depth of water at the outer end of this hooked jetty, and the photograph does not show any materially greater deposits on the windward than on the leeward side.

Mr. Higgins has described* as follows, the work that he advocates for the New Jersey shore above Ocean Grove and Asbury Park:

"It is the writer's opinion that, in most cases, where shore front for residence purposes is involved, economy, utility, and attractiveness are all best served by a system of construction designed to hold what the author names the 'plunge point' line at some distance in front of the shore line—that is to say, dry land—and that this may be accomplished by a properly designed and constructed system of groins or jetties, with a light bulkhead in the rear to prevent wash, the bulkhead being protected from the direct attack of the sea by the beach, which in turn is preserved from erosion by the system of jetties or groins.

"* * * The writer is of the opinion that, if the coast above Ocean Grove and Asbury Park received treatment similar in principle, a similar satisfactory result would be obtained and at a minimum expense."

Mr. Cresson favors the same system.

Long Branch is situated along the shore referred to by Mr. Higgins, and, in Fig. 11, Mr. Haupt shows structures of the type recommended, namely, a system of groins backed up by a bulkhead. The illustration shows that the groins have not held the plunge point at a distance from the bulkhead, and that no protecting beach has been built up to prevent the direct attack of the waves on the bulkhead. Fig. 11 is typical of what may be seen at many points along the New Jersey shore. To be sure, Mr. Higgins limits his claims to a "properly designed and constructed system of groins or jetties", and Mr. Cresson limits the height of his groins to 1 or 2 ft. above the surface of the sand, but the average engineer is unable to find any essential

* *Proceedings*, Am. Soc. C. E., for August, 1916.

difference between the structures now existing along the New Jersey shore and the structures advocated. Some explanation as to why existing structures have failed should be forthcoming before we are asked to place our faith in additional work so nearly like the old that we are unable to see any essential difference. Mr. Haupt calls attention to the fact that, in many instances, "bulkheads and jetties have proved more injurious than beneficial". Mr Dent.

At Sea Gate, on the Long Island shore, a system of groins backed up by a light bulkhead proved no more successful than the one at Long Branch illustrated in Fig. 10. As a result of damage done during the winter of 1914-15, an offshore breakwater was started during the summer of 1915 for the better protection of the Sea Gate property. Mr. Haupt has referred to two jetties built at Far Rockaway about 4 years ago. Concerning these jetties it is stated that the work is highly gratifying, as at least 500 ft. in width of beach has been gained, and the crest of the beach has been raised away above the top of the piling forming the jetties. As stated previously, when the growth of the beach is such as to bury out of sight the groins or other protection works, it is, to the writer, presumptive evidence that the cause of this growth is due to some condition entirely independent of the existence of the structures. During the winter of 1914-15, Far Rockaway and Edgemere were severely battered by storms. During the summer of 1915 several wrecked groins in this vicinity were visible, but the only work in sight which appeared to be protecting successfully the property which it was supposed to guard was the rip-rap bulkhead around the Edgemere Club. In 1910, there were at least ten groins or jetties in that vicinity, but, with the evidence before them, the land-owners of Edgemere decided, in the summer of 1915, to construct an off-shore breakwater for the protection of their property. The work was started during the same summer.

The foregoing refers to the general effect of groins, and the writer's conclusion has been that they are totally unable to build up a denuded beach or to prevent the denudation of an existing beach. It remains to examine more closely into the effects visible in the immediate vicinity of the numerous existing groins along the beaches under consideration. At the same time there will be discussed exceptions taken by Messrs. Haupt and Cresson to the writer's statement that, by forcing the littorally drifting sand into deeper water than it would reach under natural conditions, jetties and groins must inevitably cause a wastage of beach material.

It is generally claimed for groins that they stop and hold the littorally drifting sand in place until the windward beach has been built up to their tops. Thereafter, the littoral drift passes over the tops of the groins unimpeded. A few rare examples of this condition may be found along the beaches around New York City, but the normal con-

Mr. Dent. dition is very different. In the normal case there will be found in the vicinity of the groin a slight depression of the beach from about mid-tide to the crest of the berm, as shown in Fig. 12. Examples of this have been noted at many points along the New Jersey shore, including Mr. Higgins' groins at Asbury Park, and detailed notes were made during the summer of 1915, in connection with fifteen groins built according to the Case system in front of the property of the Lido Corporation, a short distance east of the end of the boardwalk at Long Beach, Long Island.

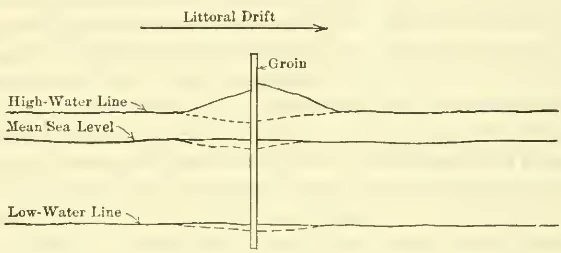

FIG. 12.—SOLID LINES REPRESENT THE NORMAL FORM OF BEACH AS OBSERVED IN THE VICINITY OF GROINS ALONG THE NEW JERSEY AND LONG ISLAND SHORES. THE BROKEN LINES REPRESENT THE FORM THAT SHOULD EXIST IF THE GROINS CAUSED A DEPOSIT.

This depression forms what may be styled a cove. During the early part of the summer, the coves in the vicinity of the Lido Corporation groins were hardly visible; the berm had a rounded appearance, as though it had been recently formed, and its width was about the same along the section covered by the groins as along the beach to the east and west. Throughout the summer, erosion was in progress and, on September 5th, the depths of the various coves were as given in Table 1; the bents are about 8 ft. in length:

TABLE 1.

Groin No.	Depth of cove.	Groin No.	Depth of cove.	Groin No.	Depth of cove.
1	2 bents	6	2 bents	11	2 bents
2	3 bents	7	2 bents	12	2 bents
3	2 bents	8	2 bents	13	2 bents
4	2 bents	9	1 bent	14	2 bents
5	2 bents	10	4 bents	15	2 bents

According to Mr. Cresson, low groins such as these should cause the sand to be deposited on both sides of the groin, in which case the beach should take the form shown by the broken lines on Fig. 12. It will be noted that the writer's statement of observed fact is here the direct opposite of what Mr. Cresson states is shown by numerous instances.

According to groin advocates, the slope of the beach on the windward side should be determined largely by the slope of the groin.

Around New York City such is not the case in fact. In the case of the Lido Corporation groins, the beach always showed one of the forms given in Fig. 6; for a variable number of bents on the shoreward end of the groins the planks were completely buried, only the tops of the posts showing through the nearly level berm; at the outer edge of the berm a typical scarp indicative of erosion was to be seen during most of the summer; below this scarp the slope of the beach was normal from the upper limit reached by the up-rush to the limit laid bare at low tide. The planks were wholly buried on the shore end, partly buried along the steeper part of the slope, and some of them were underscoured toward the outer end. Apart from the scalloped appearance due to the formation of the coves, no visible effect of the groins was noted. Mr. Dent.

Messrs. Haupt and Cresson challenge the statement that groins force the littoral drift into deeper water than would be encountered on an unimpeded beach, and thereby cause a wastage of beach material. It does not appear practicable to measure this wastage, and we must therefore depend on indications.

At high water some sand may be thrown, by the up-rush, over such groins as are shown in Figs. 10 and 11; the back-wash, however, does not lift the sand far from the bottom, and little or no beach material will be carried over a high or low groin during its downward passage. As little material passes over the groin at high water and none at low water, we should have an accumulation of sand on the windward side of the groin if it were not carried either around the end of the groin or out to sea; the absence of this accumulation leads the writer to conclude that the sand is in fact forced into relatively deep water in passing the obstruction.

At Highland Beach, N. J., there was one groin which, throughout the period of observation, was apparently performing its functions in the manner claimed by the groin advocates. On the southerly side of the groin the beach was built up to the top of the sheet-piling, and the slope was the same as that of the groin; on the northerly side the beach was about 3 ft. lower. The only explanation that the writer has been able to suggest for this exceptional condition is that the beach in that locality contained a considerable proportion of gravel. Some writers on the subject of shore protection along the British coasts have stated that either high or low groins readily hold shingle or gravel. They emphasize the fact that retaining littorally drifting sand is a much more difficult problem.

The foregoing discussion of groins should not be taken as a criticism of their use along the British coast. The conditions there are very different from those in the vicinity of New York Harbor. At all the localities in England which the writer has studied, the tides are from 8 to 20 ft. in height; in many of these localities the berm material

Mr. Dent. is shingle or gravel, and the problem of protection is more often the protection of an eroding cliff than the protection of a sandspit, as in the case of the New Jersey and Long Island Beach Colonies. This paper has been given a special and limited application, and no attempt has been made to show what parts of the discussion are of general, and what are of purely local, application.

The remaining points brought out during the discussion will be taken up in order.

Mr. Haupt states that the jetties at Belmar, N. J., arrest the wind-driven sand. It may be noted that along the Rockaway beaches brush fences are used for the same purpose. The writer's discussion was limited to the effect of wave action.

The writer did not claim that bulkheads could recover lost ground, but it was claimed for this type of structure that the semi-permanent dunes could be adequately protected, and that this form of protection would not prevent the formation of bathing beaches or berms in front of the bulkhead when other conditions were favorable.

The drift along the south shore of Long Island is of enormous magnitude, but the writer has not been impressed by the menace of this drift to the entrance channels to New York Harbor. It is believed that if Rockaway Point continues to grow in a westward direction for another 75 years, at the rate at which it has grown during the past 75 years, the results will be positively beneficial. The latest soundings in Ambrose Channel do not indicate any serious encroachment of the Long Island sand.

Mr. Higgins has evidently not understood the meaning of the term "plunge point" as used in this paper. The line marked "plunge point" on Fig. 7 moves back and forth with the rise and fall of the tides, and its location is also somewhat dependent on the height of the waves. Along the Long Island shore the distance moved by this line during a single tidal oscillation may be more than 150 ft., and it is manifestly impossible to terminate a groin on a movable line. In a tideless sea, where it might be so terminated, it is not clear how the groin would then hold the line in a fixed position.

The distance from B to B_2 in Fig. 7 is normally less than 50 ft. Such being the case, placing a groin to the left of B and another to the right of B_2 would constitute a closer spacing than the writer has ever seen seriously advocated. It is believed that Mr. Higgins has misunderstood the writer's meaning in this instance also.

There is no objection to fixing the alignment of the beach, either as it exists to-day or at some point farther seaward, provided the material for advancing the beach is not taken from the littorally drifting sand on which the leeward beaches depend for their maintenance, and provided the ends of the improved section are arranged so that they will not interfere with the littoral drift; such rectangular off-sets

as occur at Seabright should be avoided. On page 642* the writer gave his conclusions as to the proper location for a bulkhead, fixing the limit to which the sea might be allowed to encroach. Mr. Dent.

The maintenance of a bathing beach in front of a bulkhead is of great importance, one of the most serious questions with which the beach protection engineer is concerned being how to maintain such a beach. It is believed that a brief examination of the shore lines of Long Island and New Jersey will convince any engineer that the present methods have not proved successful. In many cases the measures adopted have not only failed to maintain a bathing beach, but have also failed to protect highly valuable property built on the semi-permanent dunes.

Mr. Hoar cites a case radically different from that under consideration. Long Beach, Cal., is on a bay, and the beach has in the past been built up and maintained with material found locally, and not with material brought by littoral drift from a distance. Wherever the temporary berms are enclosed within a bulkhead, as appears to have been the case at Long Beach, Cal., those responsible for such a construction should realize that, unless a new supply of material is in sight, their action will destroy the bathing beach, and the bulkhead will be subjected to a direct attack.

Mr. Hoar also misunderstands the term "plunge" as used by the writer. On the Pacific Coast where the prevailing winds blow on-shore, sands temporarily deposited above the low-water line are frequently, as soon as they dry out, blown shoreward, where they form traveling dunes. On such a shore the temporary berms are destroyed by an agency totally different from the one discussed in this paper. On some of the Pacific Coast beaches this wind action is responsible for the very flat slope that will be found between low tide and the upper limit reached by the waves at high tide. On such a beach the effect of the plunge may be much less important than on the beaches around New York City, in fact, its importance may be practically negligible.

It should be emphasized that, as the term is used by the writer for the beaches around New York City, the "plunge" always reaches clear to the bottom and causes a violent disturbance of the sand. Seaward of the plunge point the breaking waves have slight capacity for disturbing or picking up the sand. Mr. Hoar states that during calm weather and low tides much sand is carried to the outer line of breakers "where it is again picked up, carried shoreward and deposited on the beach by the up-rush." On the beaches around New York City, the resultant forces seaward of the plunge point tend to carry the sand to deep water; though the waves are able to disturb the bottom sufficiently to cause a slight turbidity in the water at the outer line of

* *Proceedings*, Am. Soc. C. E., for May, 1916.

Mr. Dent. breakers, the quantity of sand brought to the surface seaward of the plunge point is negligible. The phenomena described by Mr. Hoar for Long Beach, Cal., are not duplicated along the beaches under consideration.

Mr. Hoar also refers to the plunge as spiraling over a comparatively strong back-flow. This is a phenomenon described by Messrs. Owens and Case,* as follows:

"* * * if the waves strike the shore at such frequent intervals that the back-wash of one is met by the up-rush of the following wave, a very peculiar state of affairs is produced. At first sight, one would say, here is a case where there must be great accumulation going on, since the back-wash is met in this way by the up-rush and its scouring action presumably destroyed; but no, this is a most deceptive appearance, and is not borne out by closer observation, for instead of the checking of the back-wash by the water of the incoming wave, it simply glides up over the surface of the back-wash, thus completely reversing our first conclusion; for here we have an under current flowing seaward, and, on the top of it, a landward current. It is thus obvious that the landward current cannot pick up any material from the bottom, and some of what it may already have in suspension will be robbed from it by the down-flowing under current."

Such conditions may be found occasionally on the beaches under consideration, and, when they exist, it is to be expected that erosion will take place. The writer has often watched for this condition, but has never seen a case of the sort.

Messrs. Schwiers and Buel refer to the so-called ellipse of repose as being the typical form taken by a beach. Such a form will be found along the eroding cliffs of the north shore of Long Island and Gardiner's Bay. To some extent the same form is developed along the beaches under consideration wherever the temporary berms have been washed away and the semi-permanent dunes are subjected to attack. Where a beach is building up, and where a system of Case groins is being raised to meet this upbuilding, the form of the beach and the profile of the top of the groin will be as indicated in Fig. 6.

In stating that on the south shore of Long Island erosion takes place during northeast storms, and that, on the New Jersey coast, the erosion is caused by storms from the southeast, Mr. Schwiers has raised the question of the effect of the direction of the wind. The writer believes that the direction of the wind has little or no influence on the question of erosion or accretion. At the Condado Beach, San Juan, Porto Rico, it can be stated positively that the berms are eroded by waves of small magnitude and built up by waves of greater magnitude;

* "Coast Erosion and Fore-Shore Protection", pp. 15 and 16.

the direction of the wind in this case being unimportant. A very common statement on this subject is that on-shore winds erode a beach, and off-shore winds build it up. Relative to this the records of the Weather Bureau for New York City for the 10 years, 1905 to 1914, are interesting. During that time the wind gauge showed 336 off-shore gales for the New Jersey coast, 41 on-shore gales, and 34 gales parallel to the shore. If off-shore gales cause an accretion, the New Jersey beaches should not have suffered as they have during the past few years. In direct opposition to Mr. Schwiers' statement, that the New Jersey coast is eroded by storms from the southeast we find the statement of Mr. Higgins:* "it is the northeasters that erode the beach." (Asbury Park, N. J.) Mr. Dent.

Mr. Schwiers states that heavy masonry bulkheads have not been successful along New Jersey shores. Mr. Haupt says that they have not been tried, and the writer knows of none north of Asbury Park. The rip-rap bulkhead at the south end of Sandy Hook has protected that neck of land successfully, and the substantial pile and rock bulkhead built by the Central Railroad of New Jersey and extending from Highland Beach to Seabright has also been fairly successful. The writer believes that bulkheads of sufficient strength to protect the semi-permanent formations can be built, and that therein lies the most feasible solution of the problem with which the New Jersey beach colonies are confronted. It is a fact that sometimes, as stated by Mr. Higgins, "where the impressive fort fails, the simple trenches prove effective," but it is also a fact that it would be futile to detail a corporal's guard to stop a Prussian division.

In reference to the Case system of groins, Messrs. Schwiers and Buel seem to have been unaware of the fact that fifteen such groins were in existence a short distance from the boardwalk at Long Beach. Speculation based on experiences with structures of this type along the shores of Great Britain would not be profitable in view of the ease with which their actual effect on the beaches around New York may be observed.

The writer agrees with Mr. Cresson in his indictment of the present system, and in the statement that Seabright is a notable illustration of the evil effects of structures built without sufficient regard to a general plan.

The plans submitted by Mr. Cresson for a bulkhead at Longport, N. J.,† show a much more substantial structure than has generally been built in the past. This is a step in the right direction, but the writer cannot concede that the erection of groins in front of such a bulkhead

* *Engineering News*, April 16th, 1914, p. 832.

† *Engineering Record*, May 1st, 1915, p. 547.

Mr. Dent. gives promise of building up a protecting sand beach, or of holding an existing sand beach if a period of erosioin is due.

It is a pleasure to note that in New Jersey the subject of beach protection is receiving official notice, and it is hoped that in due course of time reports showing measured changes in the beaches, together with numerous facts in connection with the progress of these changes, may be made public. A comprehensive study, including the recording of observed facts, should explain many of the phenomena that, as Mr. Haupt expresses it, must now be attributed to "occult cosmic forces".

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

TUNNEL WORK ON SECTIONS 8, 9, 10, AND 11, BROADWAY-LEXINGTON AVENUE SUBWAY, NEW YORK CITY

Discussion.*

By Francis Donaldson, Esq.

Mr. Donaldson.

Francis Donaldson,† Esq. (by letter).‡—The writer has read with interest Mr. Werbin's paper describing the construction of the Lexington Avenue Subway tunnels, and Mr. Moulton's discussion of it. He has also noted Mr. Moulton's conclusion that the work could have been performed more economically and safely by mining with square-set timbers than by the timbering methods actually used. The writer has driven tunnels with both top and bottom headings, is familiar with mining practice, as well as with the Lexington Avenue work, and yet is unable to agree with Mr. Moulton, whose conclusion is too sweeping, to say the least.

In the first place, the choice of a method in any kind of construction must be governed by the results desired. In ore mining, the requirement is the excavation of the maximum quantity of material at the lowest cost consistent with safety, whereas, in driving a tunnel beneath a New York City street, it is not so important to excavate material at the lowest cost per ton hoisted as to excavate it in such a way as to prevent the settlement of the surrounding ground and facilitate the construction of the permanent lining. Secondly, the successful application of any method depends largely on local conditions, and a plan

* Discussion of paper by Israel V. Werbin, Assoc. M. Am. Soc. C. E., continued from November, 1916, *Proceedings*.

† New York City.

‡ Received by the Secretary, December 4th, 1916.

Mr. Donaldson

that might be best in California, where timber is cheap and intelligent miners plentiful, might not work at all in New York City.

To build the subway tunnels from 53d to 106th Streets was a big job, and it had to be done in a limited time. It was necessary to adopt methods which would enable the kind of labor available in the vicinity to be used to advantage. New York City was full of good tunnel men of all kinds, from superintendents to muckers, who had learned their business on the many aqueduct and subway tunnels recently driven in and around the city and in near-by States, but there were few miners, in the western sense. If mining methods had been required by the contract, it would have been a practical impossibility to build up an organization of miners large enough to complete the work in the required time. That tunneling methods were proper, when viewed from this standpoint, is shown by the fact that the job was completed on time and in a satisfactory manner.

To consider more specifically the different types of tunnel structures described in the paper: The express tracks in Sections 8 and 9, between 53d and 79th Streets, were in a tunnel very nearly equivalent to a standard double-track railway tunnel, driven for the most part in solid rock, and lined with a concrete arch. It is generally believed by American tunnel engineers—certainly by the writer—that the top heading and bench method is the cheapest and best for tunnels of this type, and that, where timbering is necessary, segmental timber fills the bill.

Examples of the successful use of segmental timbering in tunnels through all kinds of ground are so frequent that it is hardly worth while to refer to them; but one recent instance refutes Mr. Moulton's condemnation so emphatically that it deserves mention. A double-track railroad tunnel was driven by the Northern Pacific Railroad near Tacoma, Wash., in 1912 and 1913, through heavy clay and sand wet enough in places to have "a tendency to flow around the breast boards into the heading".* This tunnel was excavated behind a roof shield, and was timbered with segmental sets of 12 by 12-in. timbers, placed on 2-ft. centers, and lagged on the outside. Each set consisted of eleven segments. The lining proved entirely stable, and required less than 20 ft. b. m. per cu. yd. of material removed.

To return to Sections 8 and 9: it seems certain that, where a tunnel can be driven safely without timber, it is not good engineering to timber it. Segmental timber can be placed in short stretches as the excavation progresses, or after the excavation is completed if it seems necessary, and when placed it offers no obstacle to the construction of the permanent arch ring. Square-set timbering, on the other hand, must be placed as the excavation is removed, regardless of the char-

* *Engineering Record*, February 7th and 27th, 1915.

acter of the rock; it must fill the entire volume excavated, and consequently it will interfere to the greatest conceivable degree with the arch centering and the building of the arch itself. Mr. Donaldson.

A further objection to square-set timbering is this: the Lexington Avenue tunnels were driven so close to the surface that, even where the borings showed good rock, there was a likelihood of cutting a fissure filled with running ground and extending to some point below the roof line of the tunnel. Now if it is supposed that a bottom heading misses the fissure and that the next lift reaches it, the bottom will be neatly stoped out from under, and a run will be started that will stop when the soft ground gives out or the tunnel fills up. For an example, refer to the accident that occurred in driving the Mont d'Or Tunnel, under the River Bief Rouge, in 1912. This danger can be avoided by a top heading properly timbered to secure the roof. If necessary, the use of compressed air can be resorted to, as was done at 56th and 57th Streets.

Sections 10 and 11, between 79th and 106th Streets, included two general types of construction. The stretch from 79th to 98th Streets was for the most part a double-deck tunnel, two tracks wide, with a steel lower story supporting a concrete arch roof. The rock, as Mr. Werbin states, "was fairly good, and very little timbering was used". The arguments just cited, bearing on the proper construction methods for Sections 8 and 9, consequently apply with equal force here. Certainly, the conditions and methods of excavation illustrated by Figs. 11 and 13 are as nearly ideal as the most grasping contractor could desire.

From 98th Street to the end of Section 11, the tunnel varied in cross-section, but was characterized by a flat roof supported by steel bents on 5-ft. centers, with rows of columns between the tracks. This is a type of construction to which segmental timbering is entirely unsuited, and ordinary timbering methods can be used to advantage only if the rock is so solid that it will sustain itself without support over a flat roof at least as wide as a one-track structure. The contractor, nevertheless, attempted to continue the plan that had been successful on other parts of the work, and kept his air shovel working until unsound rock north of 100th Street stopped him. A heavy and elaborate system of timbering failed to prevent large over-breakage in the roof. It was considered cheaper to take down loose rock above the roof line than to hold it in place, and at one point 12 ft. of rock were removed. Large quantities of excess concrete and dry packing were required.

The writer believes that from 98th to 103d Streets, square-set timbering could have been used advantageously in the manner that Mr.

Mr. Donaldson.

Moulton suggests, and that the contractor could have saved money by using it. The cost, however, would probably have exceeded the higher figure given by Mr. Moulton, namely, $5 per cu. yd., due partly to the difficulty of organizing the job in New York City, but chiefly to the fact that the volume of rock removed in drifts and cross-cuts would have been much greater in proportion to the total volume than is the case in mining. Mine slopes are comparatively high and narrow, but these flat-roofed tunnels were low and broad.

AMERICAN SOCIETY OF CIVIL ENGINEERS

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PAPERS AND DISCUSSIONS

A METHOD OF DETERMINING A REASONABLE SERVICE RATE FOR MUNICIPALLY OWNED PUBLIC UTILITIES

Discussion.*

By Messrs. Leonard C. Jordan, H. F. Clark, and Allen Hazen.

Mr. Jordan

Leonard C. Jordan,† Assoc. M. Am. Soc. C. E. (by letter).‡—A perusal of this paper conveys the impression that the author is in favor of private ownership of public utilities, and that he is even willing to go beyond the bounds of justice in hampering municipal ownership. The writer agrees with the author in advocating private ownership of public utilities wherever such a course is advisable, but he begs leave to differ with him in one or two of the points to be mentioned herein.

The author has brought up the matter of the status of the owner of vacant lots and his responsibility to the community, so far as respects his advantages from public utilities. It is quite true that he has distinct advantages in the increased value of his holdings, and it is equally true that he has been an important factor in running up the cost of these utilities by causing them to extend their service lines past his unused property, in order to reach the used property of other owners, the people who, by making use of the utility, furnish the revenue which keeps it in existence and on a profitable basis. However, there is probably greater likelihood of general all-around justice in this respect when the utility is owned by the municipality, for, in the case of the municipally owned utility, the expense is met largely by assessment against the abutting property or by taxes on property in general. In the case of a privately owned street railway,

* Discussion of paper by J. B. Lippincott, M. Am. Soc. C. E., continued from November, 1916, *Proceedings*.

† Brooklyn, N. Y.

‡ Received by the Secretary, November 10th, 1916.

Mr. Jordan.

for instance, the owner of the vacant lots very probably would fall heir to all the latent benefits of the railway without the expenditure of a single penny. Furthermore, his neighbors must pay, by the revenues from their fares, his share of the expense of construction and maintenance, as well as for the unwelcome privilege of being hauled past his unsightly and weed-covered property. Although the author advocates private ownership, this problem which he introduces would seem to be regulated more justly for all concerned when every utility is publicly owned and properly managed.

There is a contradiction of principle cropping out at various places in the paper, which is summed up very concisely in the Synopsis, as follows:

"If the rates for service of publicly owned utilities are too low, and deficits are made up from the general tax funds, such administration is unfair to privately owned utilities and will tend to discourage the investment of private funds therein, in States practicing this policy."

Then a few lines farther along:

"Any surplus resulting from such administration [municipal ownership] should be deposited in the public treasury of the city to the credit of the general tax fund."

If it is proper to turn a surplus into the city treasury, then any deficit from operation should be remedied by drawing on the general city funds. Probably a correct business system of managing a municipally owned utility would include the keeping of strict accounts of all money matters pertaining thereto, as though it were an industry in itself and distinct from all other parts of the city government. The city treasury should be regarded as a bank, lending money to tide over unproductive periods, accepting surplus funds on deposit, and handling the bonds when their issue is required by unusual construction or development expenses.

Again, on pages 1228 and 1229,* the author advises the charging of rates higher than the nature and business of the utility would justify and the turning of surplus amounts into the city treasury. It is argued that this method is fair to the taxpayer as it reduces his taxes on real estate. The writer is unable to see any justice in placing a burdensome portion of the expense on the poorer people of the community, in order that the property owners may enjoy the advantage of reduced tax rates. Such procedure would tend to break down democracy, in that it places obstacles in the way of the poor man and makes easy the way of the man who already is rich. It is stated, relative to this matter, that the non-taxpayer is paying a fair rate for the services received, even though he is paying for a portion of the taxes of his

* *Proceedings*, Am. Soc. C. E., for September, 1916.

more fortunate neighbor, but the writer fails to detect much fairness in the plan. We might as well have municipal ownership of grocery stores, charge the high rates that would be possible under such non-competitive business, and then attempt to square matters by cutting down the taxes of those people who happen to own their homes. It is far more just, for the individual and for the community in general, to let each man pay his own way as he goes, than to attempt to equalize high rates for trolley rides and for electric lights by reducing the taxes on the same vacant lots which cause so much extra expense to utilities by increasing the length of their service lines. Mr. Jordan

The writer believes that a fair and strict accounting of the construction and operating costs of publicly owned utilities would furnish sufficient argument to convince the most stubborn that private ownership is the best plan under present conditions. He would go further, however, in the accounting than is generally done. When summing up the construction costs, all contributing factors should be included, just as they would have to be if the work were being carried on by a private company. This would require that salaries, office rent, and other expenses of public officials connected with the work be included in the bill. It would require also that depreciation of equipment and interest on its investment be reckoned, and that interest on the cost of plant and on invested construction expense be computed and included.

In compiling the accounts of the cost of operation, likewise, every part of the cost should be hunted down and charged in the proper manner. If the city has a "Commissioner of Public Works", who manages the municipally owned water-works system, then his salary and a fairly computed office rent for his rooms in the City Hall should be charged against the operation of the water-works. Furthermore, if a quarter of the time of the city treasurer and his staff is required for collecting and handling the water rents, then a quarter of their entire expense should be charged against the water revenues; and, finally, the usual tax rate should be levied against the water-works, and the tax should be paid into the city treasury and charged against the earnings of the water department. This matter of taxing might seem to be superfluous, at first thought, but a moment's consideration should suffice to convince the reader that it merely means a transfer of certain figures from one account to another, adds a negligible amount to the cost of city government, and aids in showing exactly the financial condition of the water-works department. Such a plan of accounting would form a correct basis for the regulation of rates, and would be entirely fair to the private owners of rival systems. Besides, the strict business system would furnish an incentive to efficient service on the part of the men employed in the department.

Mr. Jordan.

As a further example, a battleship is constructed at a Government Navy Yard for a certain figure, while a shipbuilding company builds the sister ship on contract at a greater stated cost. The newspaper comments mislead some people into the opinion that the only lack of perfection in the Navy is its failure to construct both boats. Yet, if all costs were tallied, the total might result in a far different opinion. The figures for the Government-built boat should include:

All the costs of plans, including the salaries of officers who oversee the work of preparation;

Office rent for all men engaged on this work, even though they occupy rooms in a Government building;

All construction costs that would be encountered by a private company doing the same work;

Salary, keep, barracks rent, etc., of all marines doing police duty in and about the ship until she is put into commission, and this item should include the expenses of officers in command of these marines;

Reasonable rent for that portion of the navy yard that is devoted to the job, or else interest, depreciation, maintenance, and taxes on the portion used;

Interest on the investment, depreciation, and maintenence of the equipment used;

Salaries, office rent, and other expenses of all officers and men connected directly or indirectly with the work;

A portion of similar expenses for all men whose duties are divided between this and other jobs, even including the Secretary of the Navy, if a portion of his work may be regarded as arising from this source;

Interest on all the foregoing amounts, computed to the day that the boat is finally put into commission;

And all other items, great or small, which directly or indirectly contribute to the amount which the Nation must finally pay for the battleship.

Some of these items are not included in the stated cost of the boat built by contract, but they should be added. The justice of a complete cost-keeping system will be realized when the reader considers the possibility of the purchase of a finished battleship from a foreign country or firm, as several other countries have done within the past few years. Besides, the people should have a right to know the total amount which such a fighting machine is costing them.

It might be contended that the office rent of the Secretary of the Navy would seem unduly high if computed on the basis of the cost of the building in which it is located and the cost of operating that building. If that is true, then the people have a right to know that they

need a new janitor in that building, or a new building superintendent, or else that they paid too much for the building originally. From another angle, if that office rent is higher than would be charged for suitable quarters elsewhere, then there is first-hand evidence that the department occupying these offices is not qualified to be placed in charge of a business requiring a high grade of efficient executive ability, such as a shipbuilding establishment. It remains that the people have paid for the building and are continuing to pay for its upkeep, and it would look like poor management on the part of the Government if there is no possible return on the first cost and running expense. Besides, failure to account for all such matters would be unfair to the contracting firm which is willing and anxious to put together a battleship for less money than it really is costing the Government. Mr. Jordan.

The result of such complete cost-keeping methods as suggested would probably lead to private ownership of public utilities, such as the author seems to prefer, a private company having a monopoly of the patronage of the community and correctly regulated by just officials of the local government. This is the ideal form of service when both private owners and ruling officials are ideal; and let us trust that we may enjoy these conditions at some time in the near future. At least, let us hope that any owning or regulating on the part of the Government will be done better than it seems to be doing with any such work now. Meanwhile, with all fairness to all parties concerned, let those engineers who are in position to decide or to influence questions of municipal or private ownership of public utilities render their decisions with impartial judgment, having in mind the furtherance of principles of justice which too often are overlooked in such affairs.

H. F. Clark,* Assoc. M. Am. Soc. C. E. (by letter).†—The author has presented views on a subject which engineers are now having to consider seriously. Where public utilities are owned by cities, it is generally found that the cities prefer to have their own way in determining how the costs of operation shall be spread, and rather resent the intrusion of scientific suggestions. The tendency is to better management of civic affairs, with centralization of power in one man or a small group of men. Engineers may yet be of some assistance to the budget makers of a municipality in determining the questions which the author has brought out. Mr. Clark.

Municipal ownership in California is steadily spreading, records for 1916 showing approximately fourteen transfers of water systems to municipalities. The aggressive element within a community generally lays siege to the water company until at last bonds are voted

* San Francisco, Cal.

† Received by the Secretary, November 20th, 1916.

Mr. Clark. and the water system is purchased. A feeling of security then comes over the minds of the people, as no longer will there be occasion for petty annoyances. The constant friction over service and rates is then passed, and, be the results profit or loss, there is always that true friend, the tax budget, to come to the rescue in times of need. A monopoly exists over the community when this competition is removed, and the city finds itself a sovereign in the matter of the regulation of this utility business.

Analysis of the paper involves accounting to a large extent. All are aware that the full cost must be met somewhere, it remaining to be determined how it shall be distributed. To bring out a little more clearly the distinctions which the author has made, Table 3 shows his distribution of the expenses.

TABLE 3.—Distribution of Water-Works Cost in a Municipally Owned Utility.

Item of expense.	Class Bearing Expense.			
	Municipality.	Consumers.	Vacant lot owner.	Realty promoters.
Maintenance and operation.......	Through taxes for public uses.	Through rates.	....	....
Depreciation	....	Through rates.	....	....
Interest	....	Through rates.	....	....
Extensions	....	....	....	Through deposits.
Betterments......	....	....	Through special tax.	....
Bond redemption.	Through taxes.	....	....	....

The author states* that municipalities have an item of expense to bear, in addition to those expenses borne by a privately owned utility, namely, the redemption of bonds within a 40-year period. The author suggests that this redemption fund should be met in the general tax levy, and therein, the writer thinks, he is in error. Cities, admittedly, are enabled, through their credit, to borrow money about 2% cheaper than a private company can finance its operations. If the city makes a 7% interest charge, as would be granted to a privately owned utility, any profit resulting under the bond rate of interest could be laid aside to redeem the bonds. If the bond rate of interest is 5%, the differential of 2% compounded annually at 4% will approximately retire the bonds in 30 years. Thus, as a fact, there is apparently no additional expense, but, in the case of a municipally owned utility, merely one more division of the same gross expenses that would be allowed a private corporation in the same utility business. The author has suggested the possibility of a profit in the management of the utility.

* *Proceedings,* Am. Soc. C. E., for September, 1916, p. 1227.

Occasionally, reports made from an audit of the books show profits, but it is rather the exception to conditions. The writer does not see why there should be any profits under the support of municipal ownership, if the rates are adjusted scientifically. It should not be the aim of a city to make its water consumers pay more than the cost of the service. Too often the consumers cannot even bear this cost, and part of it is carried under other accounts into the tax rate for the year. Mr. Clark.

Table 3 places on the consumers the depreciation charges. There is no more depreciation accruing annually in front of an improved residence lot than in front of adjoining vacant property, eliminating the item of service connections and meters. It is not clear to the writer why the only users of water should be burdened with the depreciation account, when the vacant property is increased in value, due to the presence of the main in the street. Municipal ownership is generally favored when the condition of the city as a whole will be benefited, rather than the individual condition of each consumer. Though it is true that, under a privately owned utility, the consumers have to bear this depreciation, yet it is fair, under municipal ownership, that the vacant property should bear equally with improved property this item of expense.

The distribution of the various items of cost would appear to the writer to be more equitable if as shown in Table 4.

TABLE 4.

Item of expense.	Class Bearing Expense.			
	Municipality.	Consumers.	Vacant lot owners.	Realty promoters.
Maintenance and operation.......	Through taxes for public use.	Through rates.	....	....
Depreciation	Through taxes.	....	....	....
Bond interest.....	....	Through rates.	....	....
Bond redemption.	Through taxes.	....	....	....
Extensions	....	....	....	Through deposits.
Betterments......	Through bonds or revolving fund.	....	....	....

In California it has generally been found that the maintenance and operation expenses of a water utility will approxmiate 40% of the total expenses chargeable. By the foregoing classification, an analysis will show that the consumer divides with others about evenly with the remaining 60% of the expenses which occur.

However, the writer agrees with the author that no rigid rules can be formulated in this matter, inasmuch as there are so many local situations to be met, as is shown by occasional items in the newspapers. Not long ago, an article commented on the refusal of a water-works board

Mr. Clark. to turn over a considerable sum of money to the general city treasury, in order that the tax rate might be decreased. The reasons given for the refusal were that the money would all be needed for improvements, in view of a contemplated reduction in the minimum monthly charge for water, with correspondingly less revenue for the year. This minimum was already one of the lowest in the State, but yet it seemed advisable to that board to lower it still further. Again, in another city, lately adorned to attract visitors, the park department began to use enormously increased quantities of water, drawing heavily on the safe yield of the system. The water superintendent was at his wits' end to keep up with the demand, and was unable to make any showing for his department, on account of the extreme demand of the park department, which gave him no credit for the water used.

The abuses of the sovereign water plant management may be corrected in time by the application of principles such as the author has presented. There is great need for city officials to recognize just such principles.

Mr. Hazen. ALLEN HAZEN,* M. AM. SOC. C. E. (by letter).†—This paper is timely and important. It represents a swing back of the pendulum that was set in motion when it was decided that henceforth the work of corporations in certain lines should be considered as public and not private business, and that it should be subject to public control.

The control of such corporations by public bodies is directed primarily and principally to the control of rates. The work of reducing rates in the interests of those served, formerly carried out occasionally by legislation or by Court action, is transferred to commissions created for that special purpose. The business is ordinarily expedited. It is handled by men who at least have the experience growing out of handling a considerable number of such matters. Regulation of the character of service also is undertaken, and though by no means as complete, something is accomplished.

Quite recently, perhaps since Mr. Lippincott's paper was written, another and far-reaching step has been taken; for, in one important case, Government regulation of wages paid to workers employed by such corporations is undertaken.

There is one matter, however, which cannot be regulated by Government; investors cannot be made to put more money into an enterprise, because better service is needed, or because existing rates do not furnish the money necessary, or because money is needed to pay increased wages.

When the reduction of rates and the imposition of other burdens on public service corporations has proceeded to a point where investors

* New York City.

† Received by the Secretary, November 22d, 1916.

will no longer furnish money to carry out needed improvements, it has clearly gone too far for the good of the business and the community. Mr. Hazen.

If conditions of regulation become such that private capital will not be supplied willingly to carry on the business, the only apparent way by which the public can control it further is to take over the undertakings by the right of eminent domain, and raise the needed money by taxation or by borrowing on the public credit.

It is to be noted that, in the course of the procedure which results in reducing a corporation's profits, the last step of profit reduction comes at a greatly accelerated rate, by reason of a condition which may be and probably often has been overlooked. When a corporation is making fair profits, its credit is ordinarily good, and it can borrow money at the lowest market rates. As its earnings are reduced to a point which reduces profit below normal—and, perhaps, threatens to wipe it out—the corporation's credit is impaired, and the rate at which money can be borrowed is increased.

If the profits are good, the first reduction in rates may not have this full effect, but, as reductions proceed toward the point of eliminating profit, the double effect is felt, and the final profit is reduced and eliminated quite as much by the increased cost to the corporation of getting money as by the direct loss in rates.

It is a conservative estimate that, as a result of the severe handling of corporations in some of our States in the last years, the ordinary rates which well-managed corporations have been compelled to pay in order to secure money to carry on this business, has been at least 1% per annum higher than it otherwise would have been.

To illustrate: If a corporation is earning 7% and borrowing money at 5%, it has a surplus of profit of 2%, which is a margin tending to make the business attractive to new investors and to maintain the corporation's credit. The margin is not wide, but it may answer. If in such a case, the gross earnings are 14% and the operation cost and taxes are 7%, and there is a reduction in rates, which effects a reduction in gross earnings from 14 to 13%, the direct effect is to reduce the net return from 7 to 6 per cent. The indirect result—which may not follow quite as rapidly, but is no less sure—is that, with the reduced margin to sustain credit, it is no longer possible to borrow money at 5%; and instead 6% must be paid, all the profit is wiped out, and the corporation is on the way to bankruptcy. A reduction of only 7% in the gross income may mean the difference between a margin of profit which will enable the business to be conducted successfully on conservative lines, and bankruptcy.

In the long run, the question of fair returns is boiled down to this: The returns must be sufficient to allow the business to be conducted successfully and permanently, and to permit everything to be done that needs to be done, including the securing of all new capital necessary for the reasonable extension of the business.

AMERICAN SOCIETY OF CIVIL ENGINEERS

INSTITUTED 1852

PAPERS AND DISCUSSIONS

THE YALE BOWL

Discussion.*

By Messrs. Thomas C. Atwood, J. B. French, H. C. Keith, and H. F. Dunham.

Thomas C. Atwood,† M. Am. Soc. C. E.—As has been stated in the paper, the Yale Bowl is the largest structure of its kind which has ever been built. When compared with the designs for other stadia proposed for this place, its simplicity and effectiveness at once command attention. The character of the structure, essentially of earthwork, ensures its permanence; and its safety from fire and accident is beyond question. Mr. Atwood

The original sketches called for a structure, the estimated cost of which was somewhat less than $400 000, but the several engineers and architects engaged on the work have advised certain changes, affecting the appearance and permanence of the structure, which have nearly doubled this cost.

The paper is hardly fair to other stadia in stating the cost of the Bowl as $7.35 per seat, this being the cost in its present incomplete condition. When finally completed the cost will be about $750 000, or approximately $12.30 per seat, or considerably more than the cost of the Princeton Stadium. This includes the cost of completing the concrete lining of the Bowl and placing the permanent seats, the gatehouses, permanent toilet facilities, and permanent fence. The Princeton Stadium is not fully completed, the wooden seats being lacking, but the final cost will probably not be more than $10 per seat. Of course, the difference in size must be taken into account, and a larger

* This discussion (of the paper by Charles A. Ferry, M. Am. Soc. C. E., published in October, 1916, *Proceedings*, and presented at the meeting of November 15th, 1916), is printed in *Proceedings* in order that the views expressed may be brought before all members for further discussion.

† New Haven, Conn.

Mr. Atwood.

structure of the Princeton type would undoubtedly cost more per seat. All things considered, it is probable that the Bowl is the more economical structure for the location, which is ideal for its type, and for the size demanded.

There is no doubt that the shape of the Bowl, with its curved sides, is far better than the regular stadium U-shape with straight sides. It is this horizontal curve of the sides, rather than the vertical curve produced by making the height of each riser uniformly greater than that of the one next below it, which enables the rise per seat to be small, the straight-sided structures requiring more rise in order that spectators may see all parts of the field. The importance of this is seen when it is realized that in the Bowl only 20 000 of the seats are enclosed between the goal lines extended, and that more than 40 000 are at the ends, back of the goal lines. At Princeton about 16 000 seats lie between the goal lines, and 25 000 are back of them, but only one end is enclosed, the other being open.

Of the problems in connection with the Bowl, few were of less interest than the eleventh-hour proposition to put in a track and provide a 220-yd. straight-away course by tunneling at one end. Careful estimates showed that this would involve such heavy construction that the cost would be about $50 000, and would detract considerably from the appearance of the Bowl. Experience with such tunnels, as at Syracuse, N. Y., has shown that the running conditions are not satisfactory; and, as the Committee had plenty of land available, and as an ideal track on open ground, together with a permanent stand to seat 10 000 people—as many as are likely to attend the intercollegiate track events—would cost little if any more than the tunnel, it was decided to complete the Bowl as planned and build a track and stand later.

Referring to the general construction: when the speaker was placed in charge, on January 1st, 1914, approximately one-third of the work had been completed, and the embankment had reached the top of most of the tunnels. As noted in the paper, the rolling could not be carried on between the tunnels, and it seemed improbable that the bank had been thoroughly consolidated at all points, so the top of the bank was leveled up, divided into sections, and flooded, holes being drilled down through it at the same time by iron bars or water jets about 8 ft. apart, on centers, both ways. At some points no settlement could be observed, but at others there was considerable. On this uniformly compacted base the remainder of the bank was built, as described in the paper, and with gratifying results.

The whole settlement of the completed bank is not shown by the bench-marks noted in the paper, as these were not set until the bank had been completed for nearly 2 months, but there is no doubt that the settlement was very small compared with that found in other carefully built banks, such as those under aqueducts.

The water pipe entering the Bowl was carried through the main tunnel in a small trench in the concrete floor, so that a break could not affect the foundations of this tunnel and the embankment. Mr. Atwood.

The turf strips, noted as being placed in the outside loam slope, were very successful in preventing deep wash, as was shown by a torrential rain which occurred before the seeded area had started to grow, the water in no case getting under the sod, and no gullies more than 3 in. deep being formed.

The high reinforced concrete retaining wall mentioned has performed its work well, a movement outward at the top of little more than ½ in. being the greatest noted, or corresponding to a settlement at the toe of the wall of only about ⅛ in. Relative to this matter, it may be mentioned that claim for royalty on account of the Bone patent has been made within the past year, and the speaker has done considerable work in investigating this, with the aid of searches made in the Library of the Society, and has some references to walls, built before the date of the patent, which are not included in the summary of this subject contained in *Engineering News.*

In the concrete facing inside the Bowl, the horizontal arching action was not made use of, dependence being placed on the interior retaining wall to care for any possible tendency of the blocks to slide down hill.

The lampblack placed in the mortar for the top of the facing blocks aided materially in giving them uniformity of color, as the sand used contained uncertain quantities of iron which caused some of the concrete to have a pinkish hue.

The aisles were given a top dressing of Trus-Con floor hardener, and no wear is yet perceptible; but it is difficult to say whether or not this is due to the hardener. This hardener should be applied with care by skilled men, as a few blocks, which apparently got an overdose, have turned rusty.

The inner retaining wall and the tunnel portals inside the Bowl were originally planned to have pipe-rail fences, but this was changed to heavy concrete parapet walls, at a considerable saving in cost and with a decided improvement in the appearance of the Bowl, the general idea of massive simplicity being carried out more fully.

The design of the permanent seats was another interesting problem. As finally worked out by Mr. Everard Thompson, Assistant Secretary of the Committee, and the speaker, the seat was placed on the edge of the step and supported on a steel bracket or standard which allows full play for wind and water, so that the structure can be cleaned with comparative ease.

The lumber for these seats was selected with great care. It was desirable to use edge grain lumber, and investigation showed that this could be obtained in only three woods, Douglas fir, redwood, and Western hemlock and Noble fir classed together. As redwood is likely

Mr. Atwood. to stain clothing when wet, and Western hemlock could not be obtained in sufficient quantities, Douglas fir was chosen.

Time was of great importance, and some doubts were expressed as to the possibility of getting the lumber in the 3 months available. The order was given by the speaker on August 18th, and the first carload arrived on September 29th, just 6 weeks later. When the order was given, the lumber was in the log. It was sawed, kiln-dried, planed, and shipped within 2 weeks, and was 4 weeks on the road. The kiln-drying, in this case, was preferred to open-air drying, as it boiled out the pitch pockets in the fir. All the lumber is vertical grain, clear and free from knots or other defects, except an occasional pitch pocket.

Another interesting matter was the design of the playing field. The underlying sand was so porous that a stream from a 2-in. hose would all disappear within 2 or 3 ft. of the end of the hose, so the problem was to retain moisture enough to prevent the grass from burning out, and yet have a field that would dry quickly after a rain. This was accomplished by using 18 in. of black loam and by crowning the field 1 ft., the cross-section consisting of two very flat curves, convex upward, joined by a sharper curve at the center of the field. The scheme has worked perfectly.

The summary of items of construction given is for the Bowl in its present state, and, of course, many of these will be changed when the work is completed.

In order to assist any one desirous of obtaining further information, the following bibliography of articles on the Bowl, all of which are illustrated, is given:

Engineering Record, Unsigned articles in March and November, 1914.

Engineering News, Article by the speaker, November 12th, 1914.

Yale Alumni Weekly, Article by the speaker, November 27th, 1914.

Proceedings, Connecticut Society of Civil Engineers for 1915. Paper by the author.

Journal, Boston Society of Civil Engineers, June, 1916. Paper by the speaker.

Much credit is due to the Committee of Consulting Engineers which assisted in getting the work properly started. This Committee consisted of Professor John C. Tracy, of Sheffield Scientific School, and H. C. Keith and James B. French, Members, Am. Soc. C. E. Later, Mr. French was appointed Consulting Engineer in charge of the design and construction of the work, and the first contract was prepared under his direction.

The credit for carrying on the remainder of the work is largely due to Edward G. Williams, M. Am. Soc. C. E., who served his Alma Mater without pay in the capacity of Advisory Engineer, and by his wise

advice and careful supervision brought the work to a successful conclusion. The architectural features of the Bowl were designed by the Consulting Architect, Mr. Donn Barber, of New York City, and are exceptionally effective. Mr. Atwood.

The three contracts covering the work described were finally concluded early in 1915. The speaker, however, was retained by the Committee to carry on the engineering work, and contracts were prepared covering the completion of the seating structure, permanent toilet buildings, and permanent fences, in expectation of proceeding soon with this construction. This expectation was abandoned in the spring of 1916, and the only work now being done is the construction of some 17 000 temporary seats for the Yale-Harvard game, on November 25th, 1916. This will make the total seating capacity of the Bowl on that date 77 189.

J. B. French,* M. Am. Soc. C. E.—The speaker, if he is to say anything, can most properly speak for those who advised against the building of the concrete facing directly on the embankment. Professor John C. Tracy, of the Yale Faculty, H. C. Keith, M. Am. Soc. C. E., and the speaker were asked to report on this question in November, 1912. Plans submitted to this Committee at that time were materially different from those followed in the construction. As described in the papers then submitted, the surface of the inner slope was to be cut into steps and faced with concrete $4\frac{1}{2}$ in. in thickness, laid directly on the sand, in the same manner as concrete curbs and sidewalks are built. No steel reinforcement was proposed, and all drainage was to be carried from the top of the embankment down over all the steps to the level of the playing field. At this time, also, it was hoped that the Bowl could be completed in the fall of 1913. In other words, it was proposed to build a continuous concrete lining, nowhere more than $4\frac{1}{2}$ in. thick, to cover an area measured in acres, on a new and hurriedly built embankment $27\frac{1}{2}$ ft. high. It was the opinion of the Committee that, in a structure as important and conspicuous as this was bound to be, the procedure proposed would invite undesirable defects, and that, though it might be possible to compact the embankment so that unsightly cracks might not occur, it was preferable to reduce the risk to a minimum. The Committee, therefore, though approving the general plan, reported adversely to the proposed construction of the concrete lining, and recommended a lining, lifted a few inches above the ground, made up of inverted channel-shaped slabs, supported by radial girders resting on small pedestals built in the embankment. It was proposed to make the slabs uniformly 30 in. wide, of the same cross-section, and to lay out the work so that both slabs and girders should have spans of about 20 ft., and, to the Mr. French.

* New York City.

Mr. French. greatest extent possible, be duplicates of each other. The variation in the rise of the steps or benches was to be taken care of by the form of the tops of the radial girders. It was planned to have the very large number of slabs required cast in advance in a concrete casting yard, where the concrete work could proceed independently during the progress of the earthwork, and to erect the pre-cast units very quickly with a small traveling derrick as fast as the embankment was completed.

To facilitate the construction, and at the same time take care of the rainfall on the inner lining, the slabs were not to fit each other closely, but were to be separated by slits at least ½ in. in width and were to be tilted to shed water. Rainfall was to be prevented from accumulating, and was to be allowed to escape directly through the sand and gravel, as it had always done before in the plateau in which the structure was to be built. The ability of this material to absorb rainfall had been proved to the satisfaction of the Committee by sinking a shaft at the site from the surface of the ground to below the depth of the playing field, and this shaft had cleared itself of water immediately after every heavy rainfall. To protect the newly made inner face of the earth structure from being carried down by the drainage, it was proposed to cover it with a layer of cinders, about 6 in. thick, a method found particularly effective in the construction of railroad embankments.

The Committee obtained estimates on the construction described from contractors most experienced in such work, and was convinced that the cost of the completed structure would not be increased materially by the proposed changes from the original plan.

The recommendations of the Committee were formally adopted; detailed plans and specifications were prepared and accepted; and a contract was executed for the earthwork and concrete tunnels, leaving the slab work for the interior lining to be included in a later contract. At this stage, however, other counsel prevailed, and the slab and pedestal plan was abandoned. From the description given in the paper, it appears, however, that when the time arrived for actually building the concrete lining on the embankment, notwithstanding the extremely careful and expensive methods used to compact the fill, it was not deemed wise to disregard the advice originally given, and the construction of the permanent lining was postponed until the danger of settlement should be known to have passed. It is also to be noted that the temporary construction finally placed on the embankment allows the rainfall to pass directly into the underlying sand and gravel without accumulation, exactly as was proposed in the slab and pedestal plan.

In view of the final decision, not to build directly on the embankment, it seems unfortunate that so much expense was incurred in com-

pacting the material, as this will now be done by several years of exposure to the elements. Mr. French.

It is the opinion of the speaker, and he knows it to be the opinion of others who have had experience in building railroad embankments, that the rolling of clean sand and gravel, such as was available for this work, is of doubtful advantage, and, on the other hand, that the liberal use of water while the material is being deposited is highly effective. From the levels reported by the author, it seems to have been demonstrated that the fill was well compacted, but it does not seem at all clear that this result was due, to any great extent, to rolling. As the paper states, the very considerable part of the embankment between the tunnels was not rolled, and as, in addition to the water applied while the material was being deposited, the bulk of the fill had been exposed to a winter of snow and rain, the actual advantage of the rolling does not seem to have been very conclusively demonstrated.

H. C. Keith,* M. Am. Soc. C. E.—What the speaker is inclined to say is not so much in discussion of the paper as an expression of appreciation of the great idea which Mr. Ferry presented to the world in building the stadium in this form, and in this way, at New Haven. There are very few places where such a stadium could be built satisfactorily: the nature of the soil and the location with respect to the possibilities of drainage were great factors in making this a possibility. Mr. Keith.

Although it was necessary for the speaker and his associates on the Board of Consulting Engineers, at one time, to differ from Mr. Ferry in his recommendations in some details, yet they always felt that he was deserving of great credit for the plan presented. The method of construction has also been an important factor in making the design a success.

It is disappointing that the paper gives no information as to the cost of the stadium as it is finished to-day; it is hoped that before it is printed in its final form, such figures will be included. It is also hoped that when finally printed there will be numerous illustrations, not only pictorial, but those showing the details of construction. It is well that the *Transactions* of the Society should make ample record of this construction.

H. F. Dunham,* M. Am. Soc. C. E. (by letter).†—The double rolling, with frequent disturbance of the material, was helpful in some degree in making a firm embankment. Experience has shown the advantage of vibration in solidifying sand and gravel when under pressure. Those who have had occasion to direct the tamping of loose sand and gravel for railway water tanks and building foundations will be apt to agree in this. The vibration in all such cases, even when slight, Mr. Dunham.

* New York City.

† Received by the Secretary, November 22d, 1916.

Mr. Dunham. is more effective than the pressure. This was well illustrated by experiments made a few years ago in New York City by Mr. Alfred O. Crozier in compacting sand for concrete products. The almost instant reduction in volume and hardening of the mass that occurred under slight vibration in two directions and without any pressure except the weight of the material itself was a matter of surprise and interest to all observers. In the writer's opinion, any easily operated tamping machine, even if heavy blows are not delivered, would be more effective than the rollers. This view is not to be considered as a criticism of this excellent paper, which brings distinction to its author.

MEMOIRS OF DECEASED MEMBERS

NOTE.—Memoirs will be reproduced in the volumes of *Transactions*. Any information which will amplify the records as here printed, or correct any errors, should be forwarded to the Secretary prior to the final publication.

CHARLES WILCOX HOTCHKISS, M. Am. Soc. C. E.*

DIED OCTOBER 28TH, 1916.

Charles Wilcox Hotchkiss, the son of Edgar F. and Caroline Enos Hotchkiss, was born at Plainfield, N. Y., on June 19th, 1863.

Mr. Hotchkiss began his engineering career as a Rodman on the New York, West Shore, and Buffalo Railroad, when he was 20 years old. He left that position after a short time to enter the employ of the Pennsylvania Railroad Company as Rodman and Assistant Engineer, which position he retained until August, 1886, when he went to the Michigan Central Railroad, as Assistant Engineer in charge of construction. In 1890, he was appointed Division Engineer in charge of the Chicago Division, and, in May, 1895, he became Chief Engineer of the Chicago, Hammond, and Western Railroad, in full charge of all matters in connection with its construction. In 1897, Mr. Hotchkiss held the position of Chief Engineer and Superintendent of Construction for the Chicago, Hammond, and Western Railroad Company, and of the Michigan Central Terminal Railroads, in charge of the extension of the Chicago Terminal. In 1899, he was appointed Chief Engineer of the Chicago Terminal Transfer Railway, and Consulting Engineer of the Michigan Central System.

In 1900, Mr. Hotchkiss became President of the Indiana Harbor Railroad Company, and constructed the Indiana Harbor Belt Railroad from Indiana Harbor around Chicago, as well as the Chicago, Indiana and Southern Railroad, from Chicago to Danville, Ill. After completing these roads in 1905, he effected their consolidation with the New York Central System, and became General Manager of the consolidated companies.

In 1912, Mr. Hotchkiss became President of the Chicago Utilities Company and the Chicago Tunnel Company, and, in 1913, he was called to New York City to take over the management of the various properties and interests of the late H. H. Rogers. At the time of his death, which occurred at Battle Creek, Mich., on October 28th, 1916, from organic heart trouble, he was Chairman of the Board of Directors of the Virginian Railway Company; Chairman of the Atlantic Coast Electric Railway Company; President of the Chicago Tunnel Company, the Rail Joint Company, the Richmond Light and Railroad

* Memoir prepared by the Secretary from information on file at the Society House.

Company, the Staten Island Midland Railway Company, and of various other power, light, and railroad companies.

Mr. Hotchkiss was a pioneer in the promotion and development of the Calumet Manufacturing District of Indiana, particularly in the Cities of East Chicago, Indiana Harbor, Hammond, and Michigan City. By his construction and development of the railroad facilities of that District he laid the groundwork for, and made possible, the present tremendous growth of these localities. He retained an active interest in the Calumet District until his death, and the recently completed building for the First Calumet Trust and Savings Bank, at East Chicago, which is the finest bank building in Northern Indiana and was erected under the personal direction of Mr. Hotchkiss, together with the Indiana Harbor Belt Railroad, are the two outstanding monuments to his activities in that region. He also had large real estate holdings there, extending from Laporte and Michigan City, Ind., to Chicago, Ill.

Mr. Hotchkiss is survived by his widow, Mrs. Mary Jayne Hotchkiss, and by two brothers and one sister.

He was a member of the Chicago, Mid Day, Press and Engineers' Clubs, and of the Indiana Society, of Chicago, Ill.; Duquesne Club, of Pittsburgh, Pa.; the Lawyers', Engineers', Transportation, and Richmond Country Clubs, of New York City; the Western Society of Engineers; the American Railway Engineering Association; and a Life Member of the Art Institute of Chicago. He was also a member of the Protestant Episcopal Church and the Medinah Temple Shrine.

Mr. Hotchkiss was elected a Member of the American Society of Civil Engineers on January 5th, 1898.

THEODORE HALL McKENZIE, M. Am. Soc. C. E.*

DIED MAY 3D, 1916.

Theodore Hall McKenzie was born in Yalesville, Conn., on March 29th, 1847. His father, William McKenzie, was a native of Scotland, who came to America when a young man and engaged as a contractor in the construction of buildings and stone bridges. His mother, Temperance (Hall) McKenzie, was a descendant of an old Connecticut family, and had great strength of character.

During boyhood, Theodore Hall McKenzie attended schools in Wallingford and Meriden, Conn., and, later, took the Scientific Course at the Literary Institute, in Suffield, where he studied Surveying. When still a lad, he read many scientific books, and during 1866-68 he assisted his father in the construction of public works.

* Memoir prepared by Mansfield Merriman, M. Am. Soc. C. E.

From 1868 to 1872 he worked with location and construction parties on several railroads in Connecticut and Massachusetts. During this period, he took private lessons under professors of the Sheffield Scientific School of Yale. He then became, for two years, Division and Resident Engineer on the Providence and Springfield Railroad. From 1875 to 1878, he was City Engineer of Meriden, Conn., where he prepared plans, under the direction of the late E. S. Chesbrough, Past-President, Am. Soc. C. E., for the sewerage of that city, and also built reservoirs for an addition to its water supply.

In 1878 Mr. McKenzie was elected Secretary of the Peck, Stow and Wilcox Company, hardware manufacturers, of Southington, Conn., which position he held for 10 years. During this period, he designed and built the water-works of Southington and Plainville. He also planned a sewage disposal plant for Meriden, which was the first in Connecticut. A paper on "The Water-Works of Southington, Connecticut",* was written by him and presented before the Society.

After 1888, Mr. McKenzie maintained offices in Southington and Hartford, and served as Consulting Engineer on the construction of fourteen water-works and twelve sewerage systems. Among these may be mentioned the water-works at Naugatuck, Litchfield, Wallingford, Simsbury, Terryville, Newton, and South Manchester, Conn., and Brewster, N. Y.; sewage disposal plants at Manchester, South Manchester, Norfolk, Bristol, Ridgefield, and Sharon, Conn., Johnstown and Gloversville, N. Y., and Princeton, N. J.; also water-power developments at Berlin, Conn., and Croton Falls, N. Y. Since 1906, he had been largely engaged in the appraisal of mills and water power on the Croton and Ashokan water-sheds for the supply of the City of New York, and on similar work for the Barge Canal in New York State. He was frequently an expert witness in litigations regarding such property.

In 1887, the Legislature of Connecticut constituted a State Board of Civil Engineers to inspect dams and to approve plans for new dams and reservoirs; Mr. McKenzie was a member of this Board for more than a quarter of a century, and, during part of that time, he was its Chairman.

Mr. McKenzie was Secretary and Superintendent of the Southington Water Company for 27 years, and Secretary and Manager of the Terryville Water Company for 4 years. He served as the Engineer Member of the Connecticut State Board of Health for 20 years. He was a member of the Connecticut Society of Civil Engineers, of the New England Water-Works Association, and of the American Public Health Association. He was also a member of the Masonic fraternity, and of the Baptist Church.

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* *Transactions*, Am. Soc. C. E., Vol. XV (1886), p. 885.

He was a hard worker in his profession, but, in his home, he loved the recreation of music, and out-of-doors he regarded horses as one of the best relaxations from the cares of life. His favorite counsel to young men was to learn thoroughly some business or profession and to abstain entirely from tobacco and liquors. Mr. McKenzie was held in esteem by his business associates and by the community in which he lived on account of his high character and pleasing personality.

He died suddenly, from an attack of heart desease, in his office in Southington, shortly after having arrived there to begin the work of the morning.

Albert B. Hill, M. Am. Soc. C. E., of New Haven, Conn., writes as follows regarding Mr. McKenzie:

"I was not intimately acquainted with him and was never associated with him on any work, although I was on the opposite side in several water cases. His services were much in demand as an expert in hydraulic cases, not only in his own State but in neighboring States. He was very zealous for the interests of his clients and considerate of his opponents.

"He had a very pleasant, agreeable personality, and will be greatly missed in New England engineering circles."

Robert E. Horton, M. Am. Soc. C. E., of Albany, N. Y., writes as follows:

"I knew Theodore H. McKenzie quite intimately during the period from 1906 until the time of his death. My association with him was largely in the matter of preparation of technical evidence in water-power claims on Esopus Creek. However, he was also associated with me in the defense of certain water-power and flood claims arising from the construction of the Barge Canal, we being both employed by the State of New York on these matters. We were also associated on certain matters involving water-power and water supplies, quite a number of matters, in fact, in New England. I would say of Mr. McKenzie that one might on first acquaintance easily misjudge him because of his inclination to be apparently brusque and very direct and frank in anything he had to say. The frankness and directness were true characteristics of the man. The brusqueness was apparent, not real, as on better acquaintance he was found to be exceedingly genial and cordial, in fact, I have known but few men who were so carefully and consistently loyal and devoted to their friends as Mr. McKenzie.

"In professional work Mr. McKenzie may be said to have belonged to the older school of practical engineers. The methods which he adopted for the solution of problems were nearly always simple and direct. He had had a very wide experience in engineering work in certain lines, especially water supply, sewerage, and water-power work. This experience had given him most excellent judgment in matters to which it related. He would reach conclusions at times in so simple and direct a manner as perhaps to arouse suspicion on the part of some of the younger generation who believe that correct results in similar matters can only be reached through long processes of calculation. To

one, however, who knew Mr. McKenzie's rich experience, his judgment would be most highly esteemed.

"Mr. McKenzie was at times somewhat severe in his criticism of those whom he believed to be dishonest or unprincipled in their actions. He was himself apparently incapable of anything but absolute frankness. This trait was often evident in his work as an expert witness, wherein he would very readily admit any necessary qualification of testimony he had given which was brought to his attention. This was at times perhaps a little distressing to attorneys with whom he was associated, but, on the other hand, he numbered among his most steadfast friends many attorneys prominent in the trial of technical cases, both those with whom he had been associated and those whom he had opposed."

On October 11th, 1871, Mr. McKenzie was married to Mary E. Neal, daughter of Roswell A. and Eunice (Atkins) Neal, of Southington, Conn. She survives him, with two sons, Samuel H. and William A. McKenzie, and two daughters, Eunice J. and Fanny L. McKenzie.

Mr. McKenzie was elected a Member of the American Society of Civil Engineers on September 7th, 1881.

LEONARD WARREN RUNDLETT, M. Am. Soc. C. E.*

Died October 13th, 1916.

Leonard Warren Rundlett was born in Alna, Lincoln County, Me., on September 21st, 1846. During boyhood he lived in Brunswick, Me. While he was very young his father died, after which he lived with his widowed mother and only sister. He attended school at Brunswick, and was graduated from Bowdoin College in 1868, afterward taking a post-graduate course in engineering.

Two years after graduation he went to St. Paul, Minn., where he joined the Engineer Corps of the St. Paul and Pacific Railroad Company (now the Great Northern Railway), and was engaged for two years in railroad construction work in Minnesota.

In 1872 Mr. Rundlett entered the employ of the City Engineer of St. Paul. He remained in this office, succeeding to that position nine years later. Resigning from that office in 1883, he devoted two years to planning and constructing the St. Paul Water-Works. He then resumed the position of City Engineer and remained in charge of the engineering work of the city, with the exception of one term, until 1911. During this time the city had increased from a frontier town of 25 000 people to a city of 250 000. Its public works, bridges, streets, sewers, water-works, and public buildings, costing many millions, had been planned and executed under his supervision. The administration of the Engineering Department had occupied practically all his pro-

* Memoir prepared by George L. Wilson, M. Am. Soc. C. E.

fessional life, as he had been connected with it for 38 years; during this time the city government was controlled by parties of different political views, but, in the words of the leading paper of the city after his death:

"Through them all L. W. Rundlett was recognized as a competent engineer and a personally honest man. He came through all without a taint upon his personal honesty."

The Commercial Club of the city, of which he was an active member for many years, in memorial resolutions states:

"During many years of work as a public official of this city he exemplified the highest type of official service, marked by ability, integrity, and humanity; and was in all things above the temptations of office, power, or place; caring not for public or personal honors so much as he cared for the approval of his own conscience and the merited affection of his fellow-men."

During the term he was not City Engineer, Mr. Rundlett was in charge of important hydraulic development on the Apple River, Wisconsin.

In 1913 and 1914 he was Commissioner of Public Works for the City of Moose Jaw, Saskatchewan, Canada. After this, he opened an office as Consulting Engineer in St. Paul. His health had been poor for some months; he had been suffering from heart trouble, but finally, on October 13th, the end came suddenly at his home.

He was married to Miss Mary Atwater Barry, of Milwaukee, Wis., on October 27th, 1881. Miss Barry was the daughter of Capt. Garrett Barry, a graduate of West Point, and Mary Atwater, of Wallingford, Conn. Mrs. Rundlett and one daughter, Mrs. Garritta (Rundlett) Edgerton, survive him.

Mr. Rundlett was elected a Member of the American Society of Civil Engineers on September 5th, 1883. He served as a Director of the Society in 1911-13.

FRANK OSCAR SINCLAIR, M. Am. Soc. C. E.*

Died November 15th, 1916.

Frank Oscar Sinclair was born at Burlington, Vt., on September 7th, 1860. He received his technical education at the University of Vermont, from which he was graduated in the Class of 1882.

During the summers of 1881 and 1882 he was employed as Assistant Engineer on the location and construction of the Canada-Atlantic Railway. In May, 1883, Mr. Sinclair went West and was engaged until July, 1884, as Assistant City Engineer of Leavenworth, Kans.,

* Memoir prepared by the Secretary from information on file at the House of the Society.

in charge, under the late G. W. Pearsons, M. Am. Soc. C. E., as Consulting Engineer, of the construction of a sewer system for that city.

From July, 1884, to October, 1892, he was engaged on railroad work in the West and South, as follows: July, 1884, to January, 1885, Assistant Engineer with the Missouri Pacific Railway Company, with headquarters at Atchison, Kans.; July, 1885, to July, 1887, Assistant and Division Engineer with the Chicago, Rock Island, and Pacific Railway Company, in charge of part of location and construction on lines west of the Missouri River; September, 1887, to July, 1890, Principal Assistant Engineer of the Knoxville Southern Railway; July to November, 1890, on location for the West Virginia and Pittsburgh Railroad Company in West Virginia; August, 1891, to October, 1892, Chief Engineer for the Ducktown (Tenn.) Mineral Railway Company and the Ducktown Sulphur, Copper, and Iron Company, constructing a narrow-gauge railway, erecting a crushing plant, smelting sheds, roasting furnaces, etc.

Mr. Sinclair then returned to Burlington, Vt., where he opened an office and engaged in private practice as a Consulting Engineer. He served as Chief Engineer on the construction of the Burlington Traction Company's lines, the water-power plant for Vergennes, and the Bolton Falls Dam. He was also engaged, from June, 1896, to August, 1900, as Contracting Engineer for the Pittsburgh Bridge Company in Vermont.

In 1904, Mr. Sinclair was appointed City Engineer of Burlington, Vt., and held that office until his death. He also served as a member of the Board of Aldermen from Ward 1, from 1899 to 1903; Superintendent of the Water Department from 1905 to 1909; and Member of the Board of Street Commissioners from 1913 to 1916, serving as Chairman in 1913 and 1914.

In 1910, Mr. Sinclair was appointed Consulting Engineer of the Public Service Commission of Vermont, which position he held at the time of his death which occurred on November 15th, 1916, following an operation. He is survived by his widow and three children, and by two brothers.

Mr. Sinclair was a man of the conservative type. He had many times proved himself capable of grasping large problems and of working them out successfully. He had established a reputation as a careful and accurate engineer, in recognition of which he had filled many positions of trust, among which was a recent appointment by the Secretary of the Navy as Chairman of the State Directors and Associate Members of the Naval Construction Board of Vermont. His sudden death was a distinct shock to the people of Burlington, which city he had served worthily in so many capacities, and his loss will be deeply felt by all who knew him.

He was a Past-President of the Vermont Society of Engineers, a member of Hamilton Lodge, I. O. O. F., the Algonquin Club, and a charter member of Vermont Alpha of Phi Delta Theta. He was also a member of the Official Board of the Methodist Church, and had been a teacher in the Sunday School for many years.

Mr. Sinclair was elected a Member of the American Society of Civil Engineers on November 6th, 1901.

AUGUSTUS WATEROUS AGNEW, Assoc. M. Am. Soc. C. E.*

Died September 17th, 1916.

Augustus Waterous Agnew, the only son of William Agnew, now of Victoria, B. C., was born at Montreal, Que., Canada, on June 6th, 1884. He received his engineering education at the Royal Military College, Kingston, Ont., Canada, and at the Crystal Palace Practical School of Engineering, London, England.

Returning to Canada, Mr. Agnew began his professional career, in January, 1906, on preliminary and location surveys for the Canadian Pacific Railway, with headquarters at Montreal, Que.

In July, 1906, he went to Saskatchewan as Instrumentman on the construction of the Grand Trunk Pacific Railway. In December of the same year, he went to Prince Rupert, B. C., where he was employed, as Resident Engineer, on hydrographic, topographical, and town-site surveys, and also on sewer construction, under James H. Bacon, M. Am. Soc. C. E., then Harbor Engineer, Grand Trunk Pacific Railway.

In May, 1909, Mr. Agnew left the employ of the Grand Trunk Pacific Railway to engage in private practice as a member of the firm of Ritchie, Agnew, and Company, with offices at Prince Rupert, B. C. Among other work, this firm had charge of the construction of the first water supply system for the City of Prince Rupert, including three dams, and 14 miles of supply and distribution mains. The firm was also engaged on wharf design and construction; the supervision of surveys, plans, stream measurements, and estimates for a permanent municipal water supply and power project; investigation surveys, etc., for power projects for the Prince Rupert Hydro-Electric Company, Limited, as well as the design and supervision of the subdivision of a town site of 1 000 acres, including topographical and hydrographic surveys and harbor layout, adjoining Prince Rupert, with R. H. Thomson, M. Am. Soc. C. E., acting as Consulting Engineer, and numerous small sewerage and water supply schemes, and water-power investigations.

* Memoir prepared by the Secretary from information on file at the House of the Society.

In 1913, Mr. Agnew became interested in the development of a large water-power at Stamps Falls, near Alberni, Vancouver Island, capable of developing 75 000 h. p., and prepared extensive plans, the development of which, owing to the outbreak of the war, had to be postponed. Mr. Agnew's valuable work on this project will no doubt later bear fruit.

In the spring of 1914, he moved to Victoria, B. C., where he took the contract for laying the sewer system of Equimalt which he completed.

When the 48th Battalion, Canadians, was mobilized there for service in the European war, he transferred from the Corps of Guides to that Battalion, and went overseas as its Captain and Adjutant. The Battalion, through the efforts of Captain Agnew and a few of its officers, went to the front as a unit and an Engineering Battalion of the 3d Canadian Division, and was afterward known as the 3d Canadian Pioneer Battalion. Then it was that Captain Agnew's engineering training came into service, and he made a reputation for it that became known among many of the other Canadian and British Battalions. In April, 1916, after six weeks in Belgium, constructing trenches in the Ypres salient, Captain Agnew was seriously wounded in the head and right arm by high explosive shrapnel, and subsequently suffered the loss of his left eye. After a month in the hospital, he went to Hythe, in Kent, England, where, during his sick leave, he voluntarily gave much needed instruction to non-commissioned officers and men of the Pioneers Depot at South Cæsar's Camp, Shorncliffe, England. He was offered a position as Major on the 3d Canadian Divisional Staff, but as he was eager to get back with his men, he obtained shortened leave and, on August 1st, took command once more of his old Company at the front. After six weeks he was again dangerously wounded while preparing the trenches for the infantry to hold during the battle of Courcelette, on September 15th, and died after an operation, at a Casualty Clearing Hospital near Amiens, France, on September 17th, 1916.

Captain Agnew will be greatly missed by all who knew him well enough to appreciate his many fine personal qualities as well as his ability as an engineer. He was well liked by his fellow officers and by the men whom he had trained and with whom he had fought. The splendid state of organization and efficiency reached by his Battalion was due largely to his tireless energy and ability in engineering and leadership.

He was an Associate Member of the Canadian Society of Civil Engineers, and an Associate Member of the Society of Engineers (Incorporated), of London, England.

Captain Agnew was elected an Associate Member of the American Society of Civil Engineers on July 2d, 1913.

ROBERT HAMMOND BOYNTON, Assoc. M. Am. Soc. C. E.*

Died September 18th, 1916.

Robert Hammond Boynton, the son of the late Henry P. and Emma (Hammond) Boynton, was born at Batavia, N. Y., on May 21st, 1886. He received his early education in the public schools of his home town, having been graduated from the High School in 1903. In September, 1904, he entered the Civil Engineering Department of the University of Michigan, where he remained until June, 1906, when he left college to enter the employ of the New York Central and Hudson River Railroad Company, as Chainman on grade reduction between Syracuse and Rochester, N. Y. In April, 1907, he was advanced to the position of Rodman on the same work, but resigned in October, 1907, to return to the University of Michigan, from which he was graduated in June, 1910, with the degree of Bachelor of Science in Civil Engineering.

On July 1st, 1910, Mr. Boynton entered the employ of the Missouri Pacific Railroad Company, as Rodman in the Maintenance of Way Department, with headquarters at St. Louis, Mo., being in charge of track renewal and engaged in general office and field work connected with the Department. In June, 1911, he was transferred to the Construction Department, with headquarters at Marianna, Ark., as Inspector of bridge construction on the Marianna Cut-off. In March, 1912, he was again transferred to the Illinois Division, with headquarters at Illmo, Mo., as Assistant Engineer engaged in routine office and field work connected with the Maintenance Department.

In December, 1912, Mr. Boynton entered the service of the Mississippi River Commission as Recorder on a river survey between Fort Jackson and Port Eads, La.

On April 1st, 1913, he was appointed City Engineer of Frankfort, Ind., by the Mayor, Dr. O. W. Edwards, to fill an unexpired term. In January, 1914, Mr. Boynton was re-appointed to the same office by the newly elected Mayor, Dr. Oliver Gard, and remained in that position until his death, on September 18th, 1916, following a long illness resulting from heart trouble and a complication of diseases, due to exposure and malaria contracted while he was engaged on engineering work in the Southwestern States.

Mr. Boynton was considered one of the best City Engineers that Frankfort, Ind., ever had. He had charge of the design and construction of all street and sewer improvements, and through his efforts a complete set of street and sewer records of the city was made, thereby giving the Municipal Government its first check on sewers, streets, and property owners. He had also completed a map of the City of

* Memoir prepared by the Secretary from information on file at the House of the Society.

Frankfort, which has been widely used by those interested in its public improvements.

Mr. Boynton had a genial disposition and readily made and held as friends all who met him. He was most efficient and honest, and through his conscientious efforts and steady application to duty, he received and maintained for his Department perfect work from the contractors employed thereby. He was an expert on filing systems, and at the time of his death was preparing himself for the work of a Consulting Engineer and City Manager.

Mayor Oliver Gard writes of him, as follows:

"Our city was deeply shocked when, on September 18th, the death of Robert H. Boynton, City Engineer, was announced. While he had not been a resident of this city for many years, yet we had learned to regard him highly. His work as City Engineer had been very laborious, but always satisfactory. His efficiency was never questioned. We regret his untimely death."

Mr. Boynton was married on October 15th, 1912, to Miss Zua Rice, a daughter of Mr. and Mrs. John A. Rice, of Frankfort, Ind., who, with his mother, Mrs. Emma Boynton, and a brother, R. Rae Boynton, of Rochester, N. Y., survives him.

He was a member of the Presbyterian Church of Frankfort, Ind., and of Masonic Lodge No. 475, of Batavia, N. Y. He was also a member of the American Society of Municipal Improvements, the Municipal League of Indiana, the Akhenaton Society of Ann Arbor, Mich., the Alumni Association of the University of Michigan, and the Chamber of Commerce of Frankfort, Ind.

Mr. Boynton was elected a Junior of the American Society of Civil Engineers on May 6th, 1914, and an Associate Member on April 18th, 1916.

JOSÉ PETRONIO KATIGBAK, Assoc. M. Am. Soc. C. E.*

Died May 16th, 1916.

José Petronio Katigbak was born at Lipa, Batangas, Philippine Islands, on October 4th, 1879. His parents, Mariano Katigbak and Isabel (Macarandang) Katigbak, both of Lipa, Batangas, were wealthy hacienderos, and belonged to the most prominent families in the Province.

His preliminary education was obtained in the Ateneo Municipal de Manila, a school conducted by the Jesuit Order, from which he was graduated, with the degree of B. A., in 1896, at the head of his class.

He then studied medicine for one year in the University of Sto. Tomas, Manila, but this not being to his liking, he decided to

* Memoir prepared by A. Gideon, M. Am. Soc. C. E.

study engineering, and while preparing himself to go abroad, he taught Spanish literature in the High School of his native town during 1898 and 1899, his services being given free for the benefit of his countrymen.

Mr. Katigbak then went to Europe and traveled extensively through France, Italy, Germany, and England, and, in 1900, entered King's College of the University of London, from which he was graduated in June, 1903, with the degree of Qualified Civil Engineer and the Certificate of Distinction.

He then entered the Lawrence Scientific School of Harvard University and was graduated with the degree of S. B. in Engineering, in June, 1904.

Subsequent to his graduation, he took the 1904 Special Summer Course at Harvard, specializing in Plane, Railroad, and Geodetic Surveying. On finishing this course, Mr. Katigbak entered the employ of S. D. Warren and Company, of Westbrook, Mass., remaining with that company for 7 months in the capacity of Draftsman, Surveyor and Designer.

In 1905, he returned to his native land and obtained a position with the Bureau of Public Works, where he was employed for about 4 months as Transitman, laying out the City of Baguio in accordance with the plans prepared by G. E. Burnham, Assoc. M. Am. Soc. C. E.

On February 5th, 1906, Mr. Katigbak was transferred to the Department of Engineering and Public Works of the City of Manila, and remained in the service of the City until his death. His promotion was rapid, as may be seen from his service record: February 5th, 1906, Surveyor (temporary); July 1st, 1906, Transitman (probationary); April 1st, 1907, Assistant Engineer; May 1st, 1908, Chief Surveyor; June 1st, 1910, Second Assistant City Engineer; June 3d, 1910, Instructor in Graphics, University of the Philippines, in addition to his other duties; October 1st, 1911, Superintendent of Streets and Bridges; March 4th, 1914, First Assistant City Engineer.

On several occasions, during the absence of the City Engineer, Mr. Katigbak was Acting City Engineer, and, as such, Acting Member of the Municipal Board. He was a faithful, conscientious, and hard worker, although he was not very robust. The continuous strain of his official duties undermined his health, and, in May, 1916, he left Manila on a short vacation to his home town to recuperate. While there, he contracted typhoid fever. He came back to Manila and had the benefit of the best medical talent, but his health was so undermined that he succumbed to the disease, and died on the morning of May 16th, 1916.

Mr. Katigbak's talents were varied, and he took a great interest in the fine arts, such as painting, poetry, etc. His paintings, while still a student in the Ateneo de Manila, now decorate the walls in several Government offices.

He was of a very happy disposition, and had many friends both in and out of official life, and his death was mourned by the whole population of the Philippine Islands. On the day of his funeral, all flags in Manila were half-masted, and all the City offices were closed. More than 20 000 people were in the funeral cortège. Among the honorary pall-bearers, were the Mayor and the Municipal Board, the chiefs of all the City offices, Justices of the Supreme Court, and many prominent men in civil life. The route of the procession for some miles was decorated with palms and thronged with sympathizers.

The following bodies, organizations, and offices marched in the funeral procession: Department of Engineering and Public Works; the Municipal Board of Manila; Local Members of the American Society of Civil Engineers; The Society of Engineers and Architects of the Philippines; The Columbian Association; the Bureau of Public Works, and many other organizations.

The Municipal Board, by resolution, set aside a plot for the deceased in the area reserved for the burial of illustrious and heroic dead, and, in addition, adopted the following resolution of condolence:

"Excerpt from the Minutes of the Municipal Board of May 16, 1916.

"*Whereas,* the Almighty in His Infinite wisdom has seen fit to remove from our midst our most esteemed friend and former public official, Mr. José P. Katigbak, who departed this life Tuesday, May 16th, 1916; and

"*Whereas,* it is the desire of this Body to express its condolence to the family, friends, and relatives of the deceased and its appreciation to the public generally of the efficient manner in which his services to the City of Manila as a public official had always been performed; now, therefore, be it

"*Resolved:* That the sincere sympathy and condolence of the Municipal Board be, and the same hereby are, extended to the immediate family, relatives, and friends of the late José P. Katigbak and that an expression of commiseration be tendered to them in this, their hour of bereavement; and be it further

"*Resolved:* That this Body do, and it hereby does, publicly express its keen appreciation for the manifold labors performed by him as a City official; for the betterment of conditions in the City of Manila; and be it further

"*Resolved:* That the flag at the City Hall building be displayed at half-mast until the funeral day, inclusive, on which date the flags on all City buildings shall be similarly displayed; and be it further

"*Resolved:* That a certified copy of these resolutions be sent to the widow and father of the deceased and to His Excellency, the Governor-General; and be it further

"*Resolved:* That this Board attend in a body the funeral ceremonies to be held over the remains of our departed friend."

At a later session of the Board, it was decided to name one of the principal streets, facing the New Luneta, Katigbak Boulevard.

Mr. Katigbak was married, in 1910, to Miss Trinidad Buenaventura, who, together with his father, two brothers, and one sister, survives him. He was very fond of children and his greatest regret was that he had no issue.

Mr. Katigbak was a member of The Institute of Engineers and Architects of the Philippine Islands, of which he was the first President. He was also a member and one of the founders of the Philippine Columbian Association, a society made up of Filipinos who have received college degrees in the United States.

Mr. Katigbak was elected an Associate Member of the American Society of Civil Engineers on April 1st, 1914.

WILLIAM COOPER CUNTZ, Assoc. Am. Soc. C. E.*

Died November 2d, 1916.

William Cooper Cuntz, the son of the late Emil A. H. Cuntz and Frances Cooper Cuntz, was born at Hoboken, N. J., on January 21st, 1871. His maternal grandfather, William Cooper, after whom he was named, was a well-known naturalist and one of the founders of the New York Academy of Science. His maternal grandmother, Mary Wilson, was of New England ancestry, going back to the days of the Pilgrims, and including officers and soldiers in the Revolutionary Army.

Mr. Cuntz was educated at the Hoboken Academy and at Stevens Institute of Technology, having been graduated from the latter in 1892 with the degree of Mechanical Engineer. He then became connected with the Pennsylvania Steel Company, of Steelton, Pa., first with the Bridge and Construction Department, which he represented as Resident Engineer in Boston, Mass., and as European Resident Engineer, in London, England. In these capacities he rendered many important services to his Company, notably in connection with the erection of the North and South Stations in Boston, and in securing the contract for the construction of the North German Lloyd piers, in Hoboken, N. J. He afterward entered the Sales Department, serving as Assistant General Manager of Sales, in Philadelphia, Pa., and, later, as District Sales Manager, in Steelton, Pa.

At the outbreak of the Spanish-American War in 1898, Mr. Cuntz volunteered for service in the Artillery. In 1910, he was appointed by President Taft as a delegate to the International Railway Congress held at Berne, Switzerland, the present Secretary of the Interior,

* Memoir prepared by W. R. Hulbert, Esq.

the Hon. Franklin K. Lane, being the Chairman of the American Delegation.

In the same year (1910), Mr. Cuntz severed his connection with the Pennsylvania Steel Company to become a Director and the General Manager of the Goldschmidt Thermit Company, of New York City, which position he held until his death which occurred on November 2d, 1916, at Auburndale, Mass., where he had gone on a visit for the benefit of his health which had been impaired by an operation for appendicitis a year before. Under his management the business of this Company was not only increased greatly, but equal progress was made in the technical development of the Thermit process. His wide experience in the steel industry naturally caused him to take a particular interest in the manufacture of carbon-free metals, and it is due largely to his perseverance and initiative that these metals and alloys are coming into such general use.

He is survived by his widow, who was Miss Katherine Hughes Edwards, of Hagerstown, Md., a descendant of Jonathan Edwards, and by his two children, William Cooper, Jr., and Emil Edwards. He is also survived by two brothers, John H. Cuntz, of Hoboken, N. J., and Hermann F. Cuntz, of New York City.

Mr. Cuntz was a member of the following clubs and societies: American Iron and Steel Institute, Engineers Society of Pennsylvania, Engineers Club of New York, Railroad Club of New York, Engineers Club of Boston, University Club of Philadelphia, Chemists Club of New York, Boston Athletic Association, India House, Transportation Club, Harrisburg Club, American Electric Railway Association, New England Iron League, West Side Tennis Club, Richmond Hill Association, Kew Gardens Civic Association, Kew Gardens Country Club, Oak Island Yacht Club, and the Conococheague Club of Hagerstown, Md.

Mr. Cuntz was elected an Associate of the American Society of Civil Engineers, on September 6th, 1910.

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